WHITE OAK RIVER SYSTEM STUDY
FINAL REPORT:

A PLAN OF ACTION FOR THE WHITE OAK RIVER

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WHITE OAK RIVER SYSTEM STUDY

(A Plan of Action for the White Oak River)

MARCH, 1981

Prepared For: The White Oak River Advisory Council and
Town of Cape Carteret
Town of Swansboro
Carteret County
Onslow County

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SECTIONS 2 through 6

REPORT

WHITE OAK RIVER SYSTEM STUDY

(A Plan Of Action For The White Oak River)

HENRY VON OESEN AND ASSOCIATES
CONSULTING ENGINEERS
AND PLANNERS

SECTION 2: INTRODUCTION AND BACKGROUND INFORMATION

2.1 Introduction

A study of the White Oak River was undertaken at the direction of the White Oak River Advisory Council. The Council was formed in mid 1980 as a result of concerns that the viability of the White Oak River is being threatened by continuing siltation. The Council consists of six members representing the governments of the Town of Cape Carteret, the Town of Swansboro, Carteret County and Onslow County, as well as the Commercial Fishing Industry and the Izaak Walton League. The Members of the Council are identified in Appendix A of this report. The Onslow County Planning Department acted as the Lead Agency for the study and administrator of the funding for the study. A memorandum of agreement forming the Council and stating its specific aims is also found in Appendix A.

The study was performed by Henry von Oesen and Associates, Inc., Consulting Engineers and Planners, under a contract with the White Oak River Advisory Council dated January 12, 1981.

2.2 Background

The White Oak River Advisory Council was formed as a result of expressions of concern by local interests that the White Oak River is a valuable natural resource which is being threatened by continuing siltation and other forms of pollution, particularly in the lower portions of the estuary. The Council has noted that the fisheries and shellfish productivity of the river and normal economic development of the ports of Swansboro and Cape Carteret are constrained by this continuing degredation process. In response to these concerns, the Council requested funds from the N. C. Office of Coastal Management (OCM) to perform a technical study of the problem. In recognition of the need for such a study, the Office of Coastal Management provided a grant which was combined with funds from the participating local units of government to fund this study and report.

2.3 Study Purpose and Scope

The scope of the study has been defined in a detailed work task description which is a part of the contract for the study. A copy of this task description may be found at the end of this report as Appendix B. Briefly, the study effort included a review of existing data on the hydrology, tidal hydraulics, sources of pollution, fisheries resources, land use patterns, etc., of the White Oak River Basin. This data, once compiled, was used to define the problems and to propose both structural and non-structural solutions (see Section 5).

2.4 Study Area

The general area of concern for this study is the White Oak River Basin, as defined by the N. C. Environmental Management Commission in the White Oak River Basin Plan as Sub-Basin 01. (See Bibliography, Section 8). A map of the study area is shown in Figure 2.1. Although the study effort includes the entire river basin area, the focus of attention is on the lower estuarine portion of the river south of the Seaboard Coastline Railroad Bridge near Stella. Specific emphasis is centered on the area in the vicinity of the N. C. Highway 24 causeway and bridge complex which links the Town of Swansboro with Cedar Point and the Town of Cape Carteret.

The White Oak River is used by man for waterborne commerce, extraction of fish and shellfish for food, recreation, and to a limited extent, water supply withdrawal in the upper river basin (irrigation of crops).

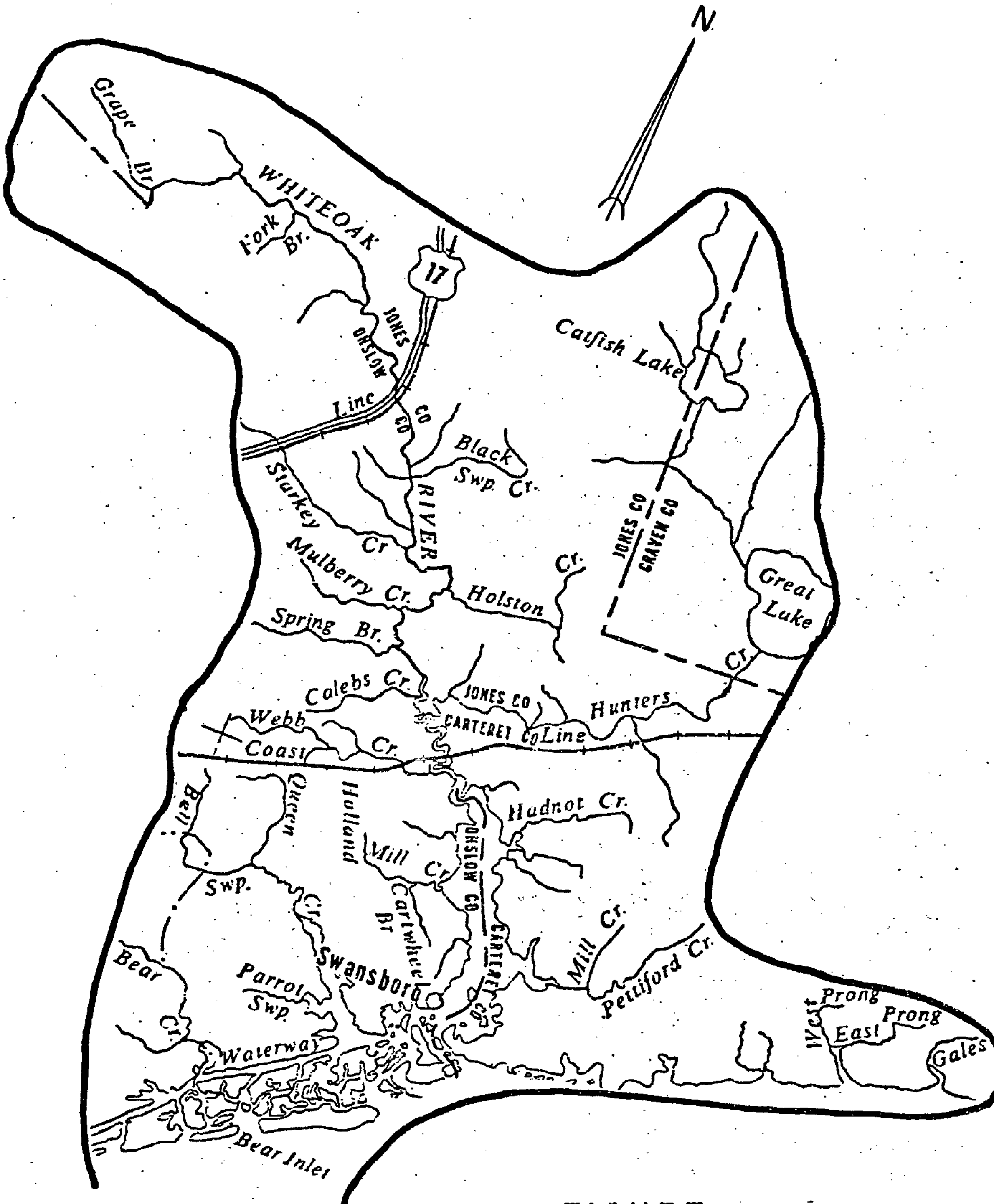


FIGURE 2.1
STUDY AREA

SECTION 3: EXISTING CONDITIONS IN THE STUDY AREA

3.1 General Description of White Oak River System

The White Oak River system is located in the south-central coastal area of North Carolina. The watershed lies entirely within the lower coastal plain with ground elevations ranging from 120 feet above sea level to sea level at Bogue Inlet. The White Oak River is relatively small and drains directly into the Onslow Bay area of the Atlantic Ocean through Bogue Inlet.

The White Oak River forms the border between Onslow, Carteret and Jones Counties of North Carolina. Its source and origins are in the Hoffman Forest of Jones and Onslow Counties. The river has a length of about 48.5 miles (78 km) from its source to where it empties into the Atlantic Ocean through Bogue Inlet. The approximate extent of the drainage area is 400 square miles. It is estimated that about 77 percent of the watershed is covered by Hoffman Forest and Croatan National Forest. There is relatively little urban development in the watershed, with Swansboro being the largest town. The major tributaries of the White Oak River are Hunter Creek, Grant Creek, Pettiford Creek, Starkey Creek, Black Swamp, and Holston Creek. All the tributaries are small and densely vegetated. The river itself averages about 0.9 miles (1.5 km) wide from the Atlantic Ocean to the vicinity of Webb Creek (see Figure 2.1). The depth is about 4 feet (1.2 m) with numerous oyster reefs and a narrow, obscure channel. The river bottom is primarily sand and mud with sand shoals along the edges. From Webb Creek to Grant Creek, the river is about 12 feet (3.7 m) deep, 490 feet (150 m) wide, and meanders. The bottom type is primarily mud and detritus and is bordered by fresh and brackish marsh. Above Grant Creek, the river flows through hardwood swamp at a depth of 5 to 14 feet (1.5 to 4.3 m). Below U.S. Highway 17, the river flows through seven distinct lakes of the Martin Marietta

Belgrade Quarry. These lakes comprise approximately 140 acres of water and range from 15 to 31 feet (4.5 to 9.5 m) in depth with steep sides and a mud bottom. The lakes were dug between 1940 and 1960 during mining operations for limestone. Water flow is very slow in the lakes except where they are connected. These lakes may act as sediment traps for upstream inputs. However, this has not been investigated or quantified by previous investigators. From the Quarry to immediately above U.S. Highway 17, the river is narrow and from 2 to 3.9 feet (0.6 to 1.2 m) deep with a rock bottom. Stream velocities are very swift in riffle areas. Above U.S. Highway 17, the river is a small typical coastal stream with the water being highly stained from swamp drainage.

The White Oak River system is predominantly tidal, except for the region above the limestone quarry and the headwaters of the tributaries. The stream velocity is slow when unconstricted.

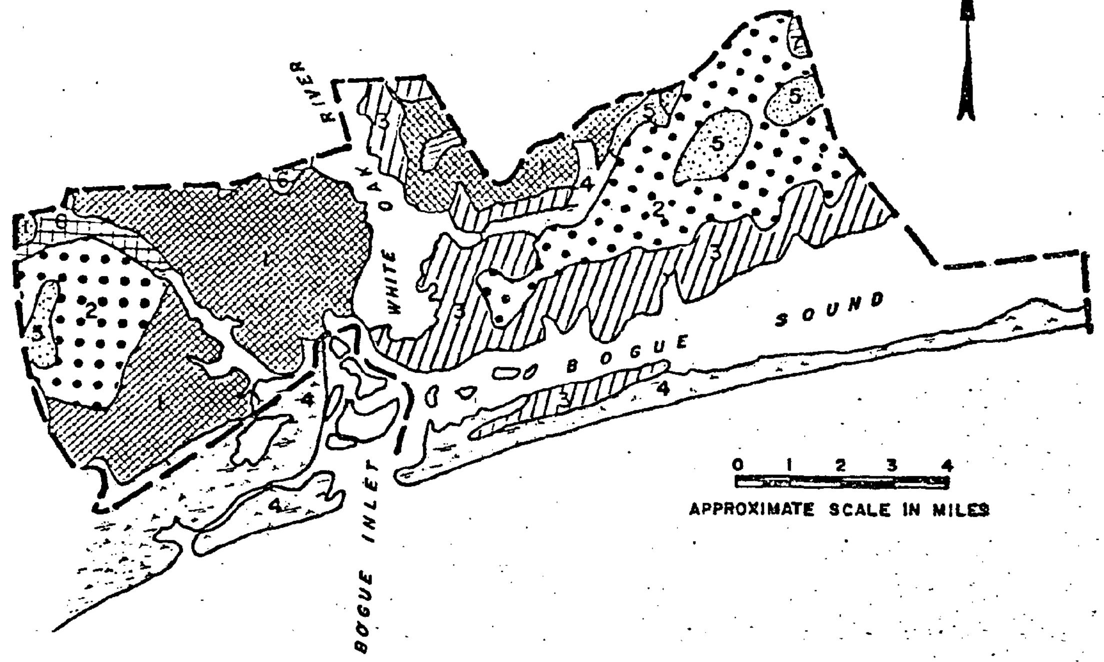
3.2 Area Geology - General

The Peedee formation forms the basement rock for the near surface (500 feet deep and less) geology of the area. Towards the coast, the Peedee lies under a thick wedge of the Castle Hayne limestone formation. The Yorktown formation (also limestone) overlies the Castle Hayne limestone and reaches a thickness of about 60 feet along the coast. A thin layer of sand and clay (chiefly sand) of Pleistocene age conceals the older formations in the interstream areas and forms the surficial sands which characterize the surface soils in the area.

3.3 Area Soils

Map 3.1 shows the general soil associations within the estuarine portion of the White Oak River Basin south of Stella, North Carolina.

GENERAL SOIL MAP



LEGEND

1 — **ONSLOW - LUMBEE ASSOCIATION:** Nearly level to gently sloping moderately well to poorly drained soils with an intermittent subsurface layer of thin hardpan and friable sandy clay loam subsoils.

2 — **LEON - LYNNHAVEN ASSOCIATION:** Nearly level somewhat poorly to very poorly drained soils with sand surface layers and dark reddish brown sandy hardpan subsoil.

3 — **LAKELAND - BAYMEADE - DRAGSTON ASSOCIATION:** Excessively drained sandy soils to somewhat poorly drained soils with sandy loam subsoils.

4 — **TIDAL MARSH - COASTAL BEACH ASSOCIATION:** Nearly level land overflowed by high tidewater and sand dunes.

5 — **PONZER - PAMLICO ASSOCIATION:** Very poorly drained organic soils 12 to 50 inches of muck over sandy to loamy textured soils.

6 — **JOHNSTON - BIBB ASSOCIATION:** Nearly level very poorly to poorly drained soils on flood plains in drainageways.

7 — **PORTSMOUTH - TORHUNTA ASSOCIATION:** Nearly level very poorly drained soils with black surface layers and gray friable sandy loam to sandy clay loam subsoils.

SOURCE: U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
RALEIGH, N.C.

MAP 3.1 - GENERAL SOIL MAP

3.4 Area Climate

The White Oak River area is located in a humid mesothermal climatic regime that is characterized by mild winters and hot, moist summers. This regime is tempered by the effect of sea temperatures and breezes in areas within 1 to 2 miles of the Atlantic Ocean. The moderating effect of the sea is clearly illustrated in the fact that Swansboro has markedly fewer days when surface temperatures exceed 90 and fall below 32 degrees Fahrenheit than do such towns as New Bern and Elizabeth City which have more inland locations.

The mean annual temperature for the North Carolina coastal region ranges from 61 to 64 degrees. July is the hottest month and has a monthly average temperature of approximately 80 degrees F. January is the coldest month with monthly means ranging from 46 to 48 degrees F. in the southern coastal areas. Temperatures along the coast seldom exceed the 100 degree mark and virtually never fall below 0 degrees F. The average dates for the first freeze in autumn and the last in spring occur during mid November and March, respectively.

Relative humidities along the North Carolina coastal region are high and average 70 to 75 percent annually. Seasonal variance is not great, but there is a slight tendency for highest relative humidities to occur in winter and lowest during spring. A distinct diurnal variation does exist with maximums generally being attained during the early morning and minimums usually occurring during late afternoon.

The White Oak River Basin receives an average of 56 inches of precipitation annually, most of which falls as rain. Precipitation in the summer is usually in the form of convectional thundershowers while in the winter it is principally of cyclonic origin. Though there are no easily discernible wet-dry seasons, greatest monthly rainfall generally occurs during July, August and September. Each of these months receives 4 to 7 inches of rainfall annually throughout the coastal region. Fall, particularly October, is the dryest part of the year, even though monthly averages would not seem to indicate this. Precipitation during this period is often associated with tropical storms and falls primarily in intense bursts of short duration. Snowfall may occur 1 to 2 times a year with a mean annual accumulation of 1 to 2 inches near the immediate coast. However, many years may pass with little or no accumulation.

The prevailing wind direction along the coast is from the southwest, except during the fall and winter months when northeasterlies caused by offshore storms may prevail. Surface wind speeds average 10 to 13 mph with maximums commonly reached during mid-afternoon and minimums just before sunrise.

The east coast of North Carolina including the White Oak River Basin is vulnerable to hurricanes; at least 43 such storms affected this region between 1910 and 1966. During hurricane periods the River/AIWW Complex receives a tremendous influx of sediments. When storms are of unusual severity, new inlets may be formed or existing ones closed. The hurricane season begins in June and often extends into November. From June to September the greatest number of storms originate over the Atlantic Ocean, frequently in the vicinity of the Bahama, Windward or Leeward Islands. These storms will usually move inland well south of the State, or move northward paralleling the coast. The latter is the type that most frequently crosses the North Carolina coast. However, most of these have storm centers which pass well offshore and thus, damage is usually restricted to that associated with heavy rain, high tides, and seas. As the hurricane season progresses into late September and October, the center of maximum activity shifts to the western Caribbean. Storms originating in this region frequently move inland over the Florida land mass and travel in a northerly to northeasterly arc. By the time they reach North Carolina, they have lost most of their intensity because of their overland passage.

Northeast storms which occur primarily during the fall and winter are perhaps a more significant source of erosion along the coastal area than are hurricanes. These storms are created when low pressure areas move up the coastline causing a counterclockwise flow of moisture-laden air. The storms are accompanied by heavy rain and strong northeast winds which may cause unusually high tides and seas. Duration of the storms is variable but they often persist for from 2 to 5 days.

3.5 Plant and Animal Communities

The planning area lies within the coastal plain region of North Carolina. The area serves as a meeting ground for salt tolerant and fresh water biotic communities. The interaction of fresh water with saltwater and the mild climate provide numerous habitats for a large diversity of aquatic and terestrial wildlife and flora. Table 3.1 enumerates the general biotic communities and their respective residents for the coastal region, including the White Oak River Basin.

"The Atlantic Coast Ecological Inventory" (see Bibliography) indicates that the many marshes, inlet, and bays in the White Oak River area provide excellent habitats for a variety of species. Shorebirds, wading birds, and waterfowl migrate along the coast and overwinter in many of the bays and sounds. Wild turkey is common in a broad band of upland forests paralleling the coast and several mammals, particularly deer, are recreationally important.

Croatan National Forest occupies over 123,887 hectares (306,000 acres) and provides sport hunting opportunities for a variety of game animals. This forest contains Great Lake, which has a shoreline that is considered to be one of the better localities for birds in North Carolina. Nesting birds in the forest include ospreys, herons, double-crested cormorants, and warblers.

TABLE 3.1

PRINCIPAL BIOTIC COMMUNITIES[1]

ommunity	General Location(s) Relative to Soil Associations	Dominant Species In Canopy	Dominant Species In Sub-Canopy	Dominant Shrubs & Herbs	Principal Animal Species	Endangered Species Present	Comments
. Hardwood Forest	1, 2	Water Oak, Post Oak, White Oak, Red Maple, Tulip Poplar, Sweet Gum, Southern Red Oak, Hickory, and Black Gum. Occassional large single *Loblolly Pines*, or Long Leaf Pines may occur.	Same as for Canopy. Flowering Dogwood Common.	Pepper Bush, Wild Olive, Catbrier, Muscadine, Bamboo, Wild Ginger, and Yellow Jasmine.	(a) Birds-Red-Shouldered Hawk, Screech Owl, Yellow-Shafted Flicker, Downy Woodpecker, Blue Jay, Carolina Chickadee, Tufted Titmouse, Carolina Wren, Yellow-Throated Warbler and Cardinal. (b) Mammals-Eastern Gray Squirrel, Flying Squirrel, Cottontail Rabbit and Whitetailed Deer. (c) Amphibians and Reptiles-(Very Common): E. Box Turtle, Green Snake, Black Racer, Southern Copperhead, and Slimy Salamander.	None	Consideralbe variations possible due to differences in past disturbances and localized soil conditions. Peak of succession.
. Mixed Pine Forest	1, 2	Loblolly Pine or Long Leaf Pine associated with species present in Hardwood Forest above.	Same as for Hardwood Forest.	Same as for Hardwood Forest.	Same as for Hardwood Forest.	None	Relative amounts of Pine and Hardwoods reflect types and degrees of past disturbance. Without disturbance succession is to Hardwood Forest.

TABLE 3.1 - Continued

PRINCIPAL BIOTIC COMMUNITIES

mmunity	General Location(s) Relative to Soil Associations	Dominant Species In Canopy	Dominant Species In Sub-Canopy	Dominant Shrubs & Herbs	Principal Animal Species	Endangered Species Present	Comments
Pine Forest	1, 2, 3	Two Types Exist: (a) Solid Pine Canopy dominated by Loblolly Pine or (b) Sparce Canopy dominated by Long Leaf Pine.	Red Maple, Sweet Gum, Sassafras, Black Cherry.	Same as for Hardwood Forest plus Sweet Bay, Dwarf Sumac and Fetter Bush. Herbs include Virginia Chain Fern, Grasses and Sedges, Golden Rod, Meadow-Beauty, Yellow Eyed Grass, Milk Wort, and Wild Vervena.	(a) Birds-Red-Shouldered Hawk, Screech Owl, Red Headed Woodpecker, Carolina Chickadee, Tufted Titmouse, Carolina Wren, Yellow Throated Wabler, Yellow Throat, Hooded Warbler, Summer Tanger, Indigo Bunting and Blue Grosbeak. (b) Mammals-Striped Skunk, Ea. Gray Squirrel, Ea. Fox Squirrel, and Whitetailed Deer. (c) Reptiles and Amphibians-Rat Snake, Black Racer, Canebrake Rattler, Oak Toad, Spade-Foot Toad, Narrow-mouth Toad, and Pine Woods Tree Frog.	None	Canopy type (a) found where natural succession or planting has ocurred on areas that were once cultivated. Canopy type (b) Long Leaf Pine prefers moist sites. Succession to mixed Pine-Hardwood Forest possible.

TABLE 3.1 - Continued

PRINCIPAL BIOTIC COMMUNITIES

mmunity	General Location(s) Relative to Soil Associations	Dominant Species In Canopy	Dominant Species In Sub-Canopy	Dominant Shrubs & Herbs	Principal Animal Species	Endangered Species Present	Comments
Swamp Forest	4	Bald Cypress along with Red Maple, Swamp Gum, Ash, Water Hickory, Swamp Chestnut, Oak and Tupelo.	Younger individuals of Canopy.	Royal and Cinnamon ferns, Gallberry, Titi, Bamboo, Catbrier, Swamp Rose, Virginia Willow, Wax Myrtle, Water Willow. Under dense Canopy: Lizard's Tail, Royal Fern, Pennywort, Cinnamon Fern, and Spanish Moss on trees.	(a) Birds-Downy and Pileated Woodpeckers, and Yellow Shafted Flicker are common. Carolina Chickadee, Tufted Titmouse, Blue-Gray Gnatcatcher, and Prothonatary Warbler. (b) Mammals-Opossum, Racoon, Bobcat, Gray Squirrel, Marsh Rabbit, Rice Rat, Flying Squirrel and Muskrat. (c) Reptiles and Amphibians-Mud Snake, Yellow Rat Snake, Eastern Cottonmouth, Canebrake Rattlesnake, Squirrel Treefrog, Green Treefrog, and Southern Lepard Frog.	None	Occurs along small streams with low flows.

TABLE 3.1 - Continued

PRINCIPAL BIOTIC COMMUNITIES

mmunity	General Location(s) Relative to Soil Associations	Dominant Species In Canopy	Dominant Species In Sub-Canopy	Dominant Shrubs & Herbs	Principal Animal Species	Endangered Species Present	Comments
Mixed Marsh	1, 3, 6	Loose Stands of Cypress, Swamp Gum, and Red Maple occur along banks of the creeks in the area.	N/A	Giant Cord-grass.	(a) Birds-Herons, Egrets, Ducks, Vultures, Hawks, Rails, Gulls, Sandpipers, Plovers, Owl, Snipe, Wood-peckers, etc. (b) Mammals-Whitetailed Deer, Racoon, Mink, Marsh Rabbit, Rice Rat with limited number of River Otters and Muskrats. (c) Reptiles and Amphibians-American Alligator, Yellow-Bellied Turtle, Brown and Banded Water Snakes, Eastern Cottonmouth, Broken-Striped Newt and several species of frogs.	American Alligator	Chief migrant water fowl habi-tat where open water occurs.

TABLE 3.1 - Continued

PRINCIPAL BIOTIC COMMUNITIES

ommunity	General Location(s) Relative to Soil Associations	Dominant Species In Canopy	Dominant Species In Sub-Canopy	Dominant Shrubs & Herbs	Principal Animal Species	Endangered Species Present	Comments
. Pocosin	5	Pond Pine with less frequent Red Maple.	Evergreen Shrubs.	Where shrub layer is continuous herb layer is not existant.	(a) Birds-Carolina Wren, Catbird, Robin, Hermit Thrush, White-eyed Vireo, Yellow Throat and Ea. Towhee. (b) Mammals-Marsh Rabbit, and White-tailed Deer. (c) Reptiles and Amphibians-Southern Cricket Frogs and a few other reptiles.	None	Limited occurance within area.
. Tidal Marshes	3, 4	None	None	Smooth Cord-grass, in low marsh and Salt-Meadow Cordgrass, Sea Ox-Eye, Needle Rush, and Sedges in high marsh.	(a) Birds-Marsh Hawks, Sparrows, Waterfowl and various Seabirds. (b) Mammals-Muskrat and Nutria. (c) Reptiles-Terrapins. (d) Invertebrates-Fiddler Crabs, Mud Snail, Ribbed Mussel, Blue Crab.	None	Occurs adjacent to Eastern sounds and western margins of Barrier Islands. Some areas disturbed by development.

Abundant populations of the American Alligator, several colonies of red-cockaded woodpeckers, and nesting ospreys make the White Oak River and its marshes an important habitat for rare or endangered wildlife. The Loggerhead Sea Turtle, an endangered species, nests at Hammocks Beach at the mouth of the White Oak River.

3.6 Land Use

Land uses within the White Oak River Basin were characterized based on the Land Use and Land Cover maps published by the U. S. Geological Survey (see Maps 3.2, 3.3 and 3.4). As can be seen from the maps, most of the land adjacent to the river and its tributaries is forest land or forested wetland. Agricultural use of land is next in extent, followed by urban and built-up uses. It appears that silvicultural and agricultural practices have the greatest potential impact on the river. Present urban uses have a relatively lesser impact. The Water Quality Management Plan, White Oak River Basin (Subbasin 01) presents the distribution of land uses as shown in Table 3.2.

3.7 Water Quality

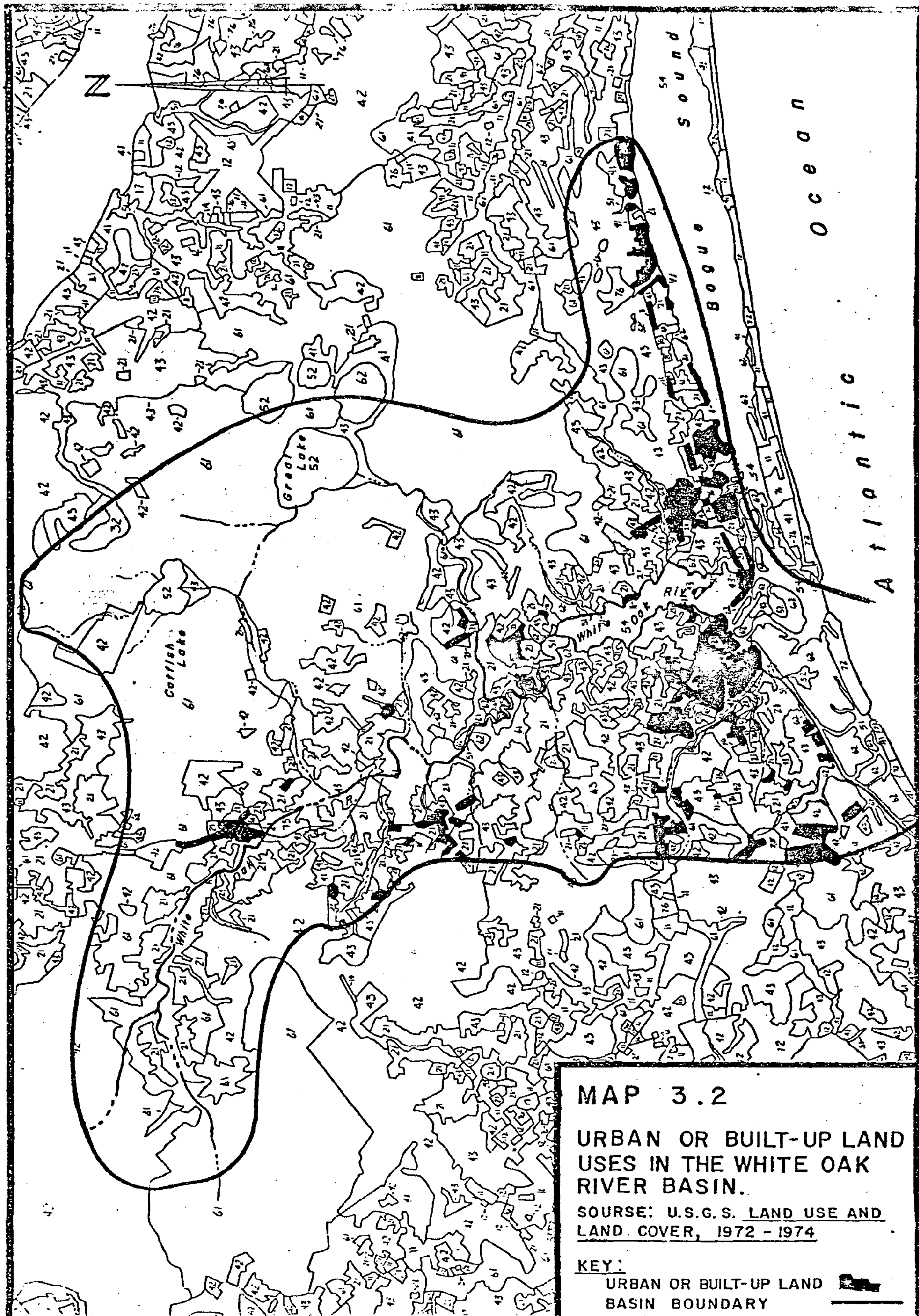
Only limited data on the water quality of the White Oak River is available from existing references. Back in the early 1950's the State Stream Sanitation Committee of the N. C. State Board of Health conducted a pollution survey of the White Oak River Basin (see Bibliography of References, Section 8). The only significant source of pollution noted in the entire White Oak River drainage basin was the partially treated wastewater discharge from the Town of Swansboro. As a result of this survey, the Stream Sanitation Committee established a restricted area around the Swansboro discharge to protect the public health. The survey report also identified pollution from domestic wastes from individual homes from Maysville and Belgrade which discharged to the upper river from the

TABLE 3.1 - Continued

PRINCIPAL BIOTIC COMMUNITIES

mmunity	General Location(s) Relative to Soil Associations	Dominant Species In Canopy	Dominant Species In Sub-Canopy	Dominant Shrubs & Herbs	Principal Animal Species	Endangered Species Present	Comments
Beach Dune-Scrub Thicket	3, 4	None	None	Sea Oats on Dunes, and Sea Myrtle, Groundsel, Marsh Elder and Sea Ox-Eye in thickets.	(a) Birds-Laughing Gulls, Herring Gulls, Common Terns, and Black Skimmers on Dunes and Grackles, Red-Winged Blackbirds, Mocking-birds and Warblers in shrub thicket. (b) Reptiles and Amphibians-Toads in tickets. (c) Invertebrates-Ghost Crabs on dunes.	None	West Bogue Banks is least disturbed example of this community in this area.
Maintained Fields	1, 2, 3	Scattered Pines may occur.	N/A	Low Grasses, Sedges, Weeds and various agricultural crops.	Migrants from adjacent biotic, communities, e.g. Pine Forest.	None	Scattered throughout area. Succession to "Old Fields" and Pine Forest if left undisturbed.

/ Source: Swansboro Area 201 Facility Plan

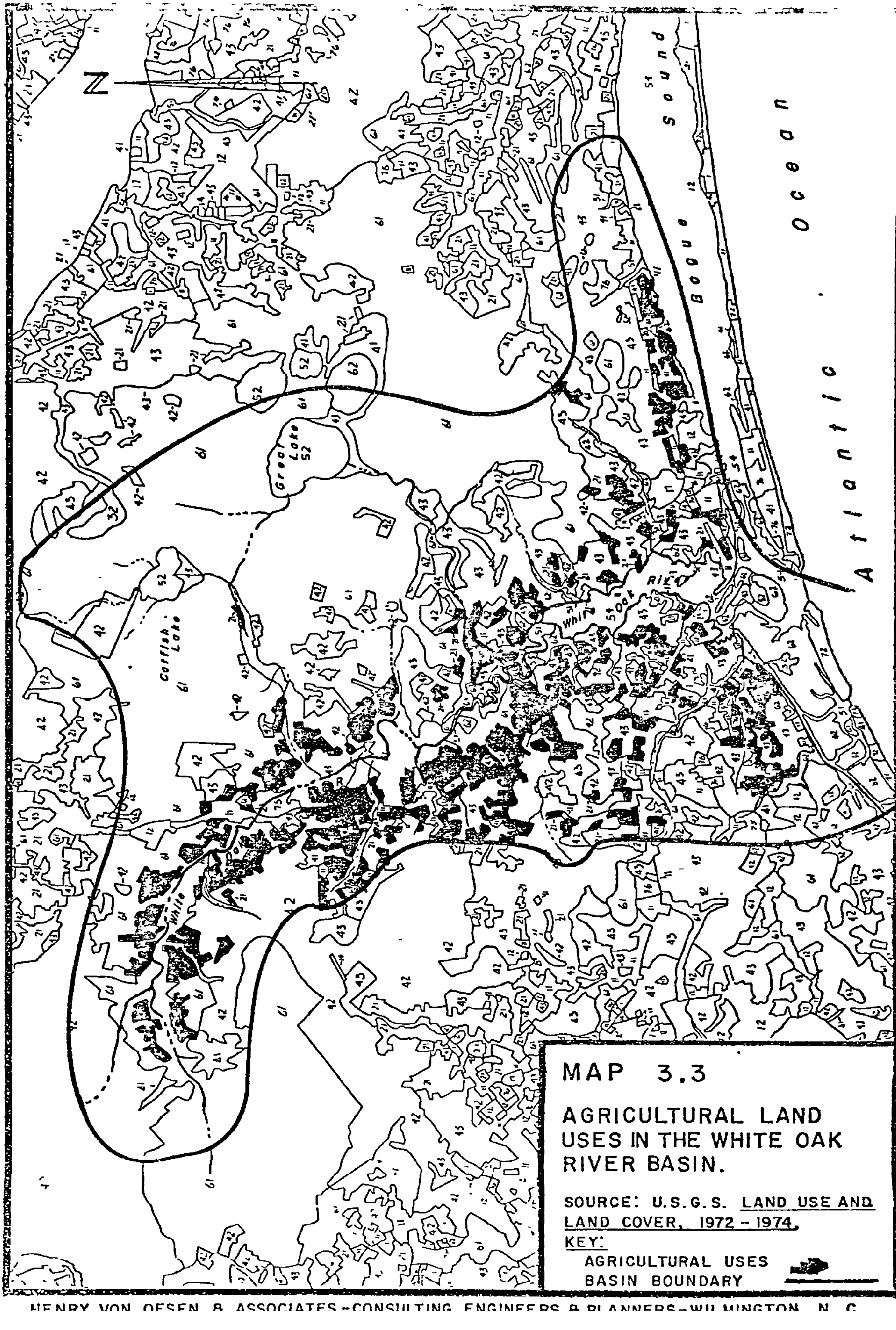


MAP 3.2

URBAN OR BUILT-UP LAND USES IN THE WHITE OAK RIVER BASIN.

SOURSE: U.S.G.S. LAND USE AND LAND COVER, 1972 - 1974

KEY:
URBAN OR BUILT-UP LAND
BASIN BOUNDARY



MAP 3.3

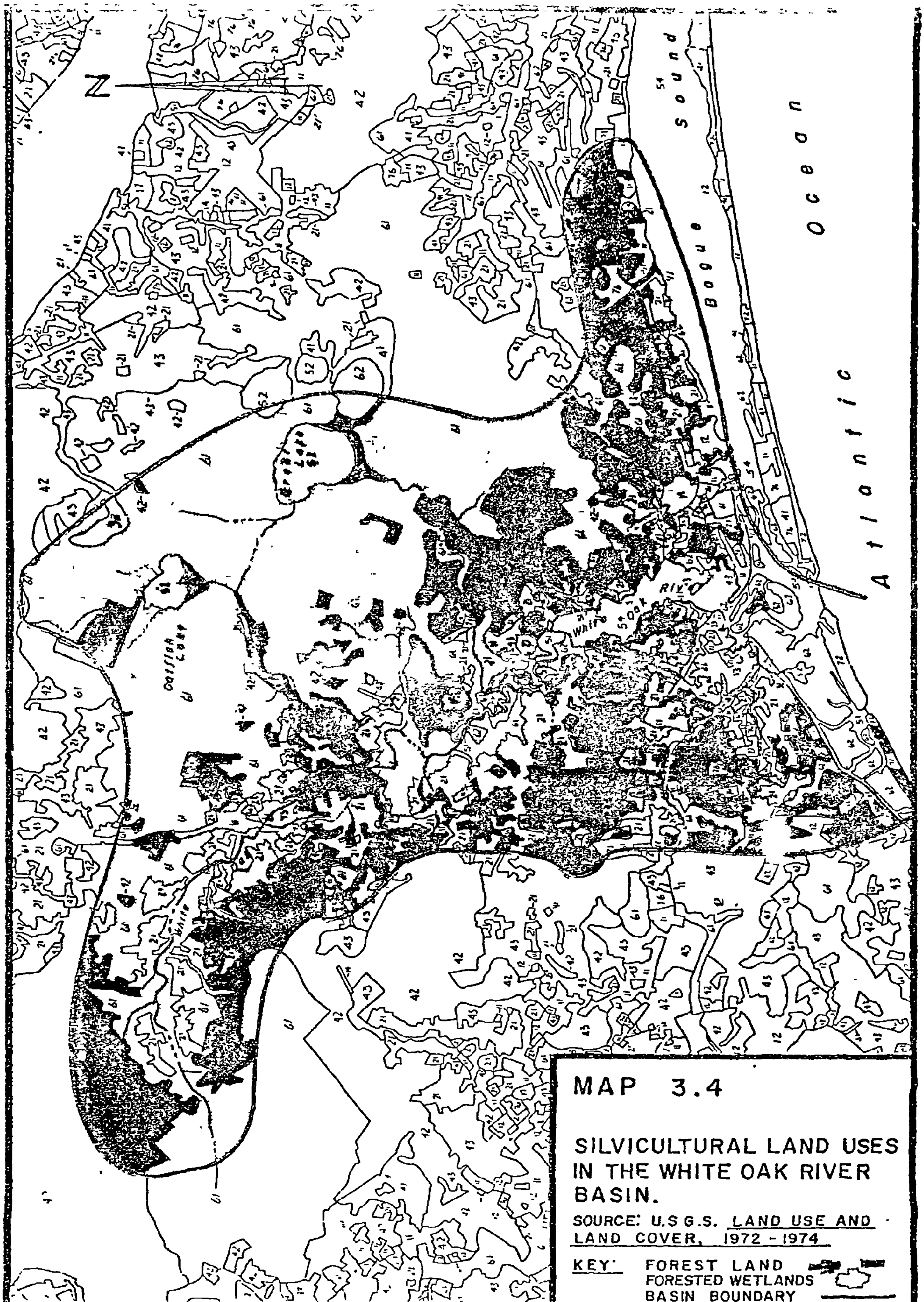
AGRICULTURAL LAND USES IN THE WHITE OAK RIVER BASIN.

SOURCE: U.S.G.S. LAND USE AND LAND COVER, 1972 - 1974.

KEY:

AGRICULTURAL USES

BASIN BOUNDARY



MAP 3.4

SILVICULTURAL LAND USES IN THE WHITE OAK RIVER BASIN.

SOURCE: U.S.G.S. LAND USE AND LAND COVER, 1972 - 1974

KEY: FOREST LAND
FORESTED WETLANDS
BASIN BOUNDARY

HENRY VON OESEN & ASSOCIATES - CONSULTING ENGINEERS & PLANNERS - WILMINGTON, N. C.

TABLE 3.2

Land Uses
White Oak River Basin[1]

	Category of Use	No. of Acres	% of Total
1.	Federal	116,100	28.9
2.	Urban	1,000	0.3
3.	Water Areas	50,000	12.5
4.	Cropland	32,900	8.2
5.	Pasture	2,000	0.5
6.	Forest	167,800	41.8
7.	Other	31,500	7.8
	Totals	401,300	100

[1] Source: Water Quality Management Plan, White Oak River Basin, Sub-Basin-01. 1975. NCDEM, Raleigh, N. C.

mouth of Grape Branch to the mouth of Hunter Creek (see Figure 2.1).

Beginning in 1968, the N. C. Division of Environmental Management established several water quality sampling stations in the White Oak River. The locations and descriptions of the stations are shown in Figure 3.1. Detailed records of the results of the sampling are found in the Water Quality Management Plan published in September, 1975 by the N. C. Environmental Management Commission (see Bibliography). In summary, the results show good quality water with virtually no water quality standards contraventions. However, all stations show slight water quality degradation on occasion. These conditions have been attributed to land runoff and, in the case of stations near Swansboro, discharges from the Town of Swansboro's former primary wastewater treatment facility.

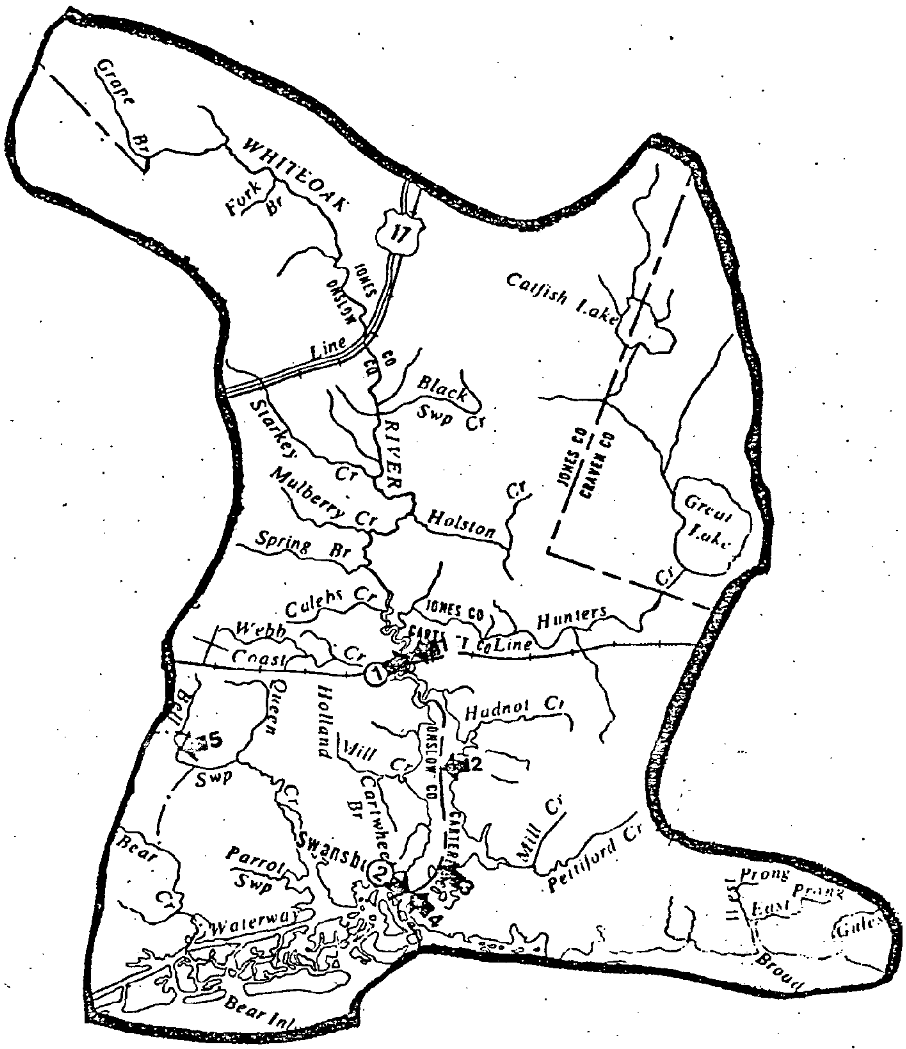
In 1979, the Town of Swansboro began operation of a new tertiary wastewater treatment facility located at Fosters Creek southwest of the Town. Discharges to the White Oak River from the old facility have since ceased and a general improvement in water quality in the lower estuary has been noted by NCDEM from recent samplings.

Certain zones within the study area have been degraded by pollutants to the extent that the harvesting of shellfish for marketing has been prohibited by the Office of the North Carolina Shellfish Sanitation Program, Division of Health Services, based in Morehead City, North Carolina. Those areas which have been closed to shellfishing are shown on Map 3.5. The prohibited areas include most of the upper river estuary north and west of Godfrey Branch, Hargetts Creek, Holland Mill Creek, Stevens Creek, Pettiford Creek, and an extensive zone in and around the Town of Swansboro including Queens Creek. The total shellfish harvesting area consists of some 8,500 acres of which 1,292 acres (15.2 percent of the total) are closed to shellfishing.

FIGURE 3.1

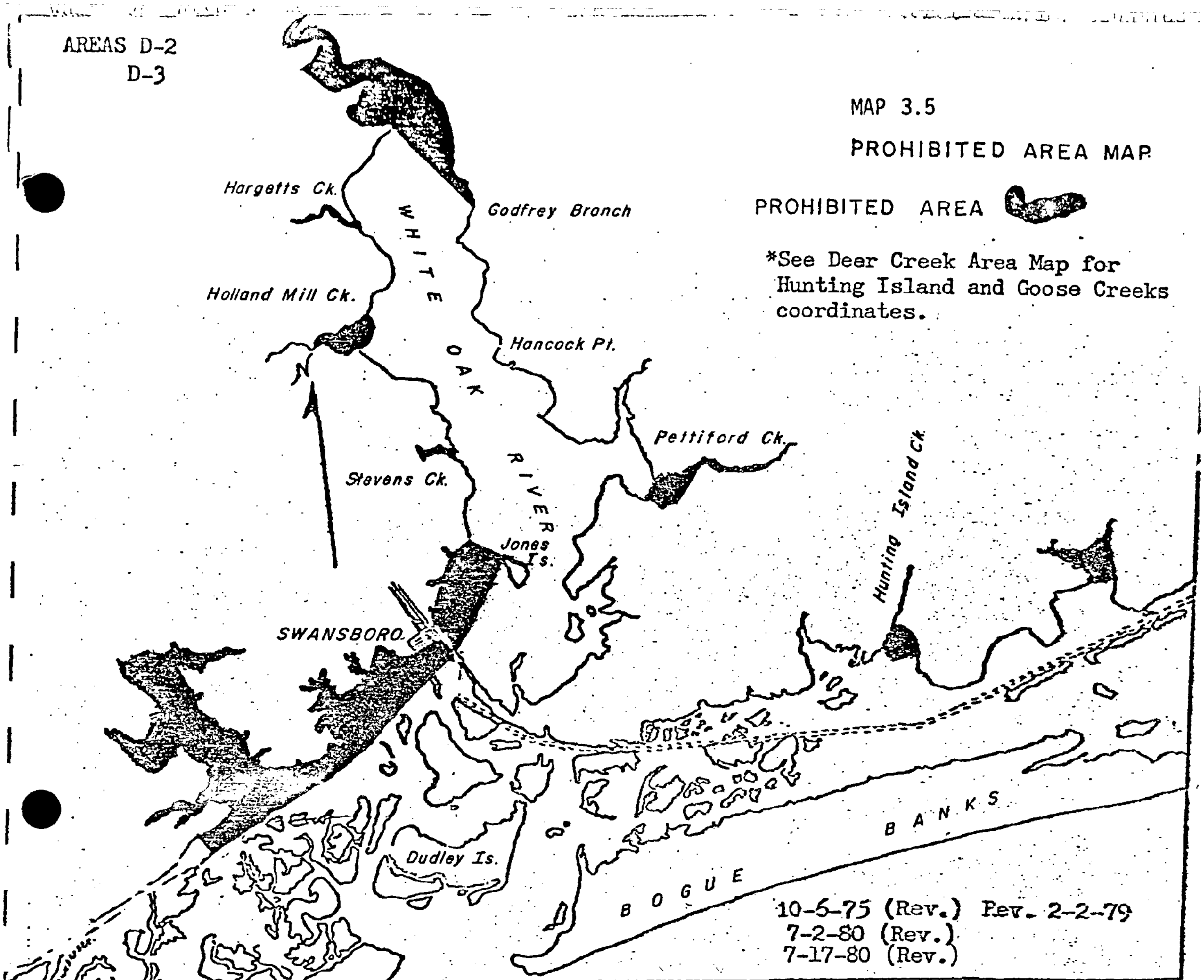
DIVISION OF ENVIRONMENTAL MANAGEMENT

WATER QUALITY STATIONS



LOCATION NUMBER	STATION NUMBER	TYPE	STATION NAME
1	27	Secondary Network	White Oak River near Stella, NC
2	28	Secondary Network	White Oak River near Peletia, NC
3	29	Secondary Network	White Oak River near Swansboro, NC
4	30	Secondary Network	White Oak River at Swansboro, NC
5	31	Secondary Network	Bell Swamp at Starling, NC
1	02092744	Old Primary	White Oak River at Stella, NC
2	02092760	New Primary	White Oak River at Swansboro, NC

AREAS D-2
D-3



No person shall take or attempt to take any oysters or clams or possess, sell, or offer for sale any oysters or clams taken from the following areas, at any time:

(22) White Oak River Area:

(a) In White Oak River and all its tributaries upstream from a straight line running from the south side of the mouth of Godfrey Branch 300° M, to a point of marsh, and in Pettiford Creek, from its origin to a point one mile downstream from the N. C. Highway 58 Bridge over said stream; in Stevens Creek, in Holland Mill Creek and its tributaries and within three hundred yards of its mouth; and beginning at a point on Mt. Pleasant at 34° 42' 03" N, 77° 06' 50" W; thence in a straight line to a point on the northern end of Jones Island at 34° 41' 54" N, 77° 06' 30" W; thence in a straight line to eastern end of Highway 24 Bridge at Swansboro 34° 41' 08" N, 77° 06' 58" W; thence to a point on the southeast shore of the ICWW at 34° 40' 13" N - 77° 08' 00" W, near Beacon #49; thence following the southeast shore in a southwesterly direction, crossing all tributaries, to a point on the shore at 34° 39' 19" N - 77° 09' 31" W, near Channel Marker #53; thence straight across ICWW to a point on the northwest shore at 34° 39' 25" N - 77° 09' 36" W. This is to include all the waters of Queens Creek.

(b) All waters upstream from a line across Hargetts Creek beginning at a point on the north shore at 34° 44' 54" N - 77° 08' 12" W; thence to the south shore at 34° 44' 44" N - 77° 08' 06" W.

The sanitation requirements for approved shellfish growing areas are set by the U. S. Public Health Service in its National Shellfish Sanitation Program Manual of Operations, Part 1, Sanitation of Shellfish Growing Areas (1965 Revision) and are as follows:

> "Growing areas may be designated as approved when:
>
> (a) The sanitary survey indicates that pathogenic micro-organisms, radionuclides, and/or harmful industrial wastes do not reach the area in dangerous concentrations, and
>
> (b) This is verified by laboratory findings whenever the sanitary survey indicates the need. Shellfish may be taken from such areas for direct marketing."
>
> "Satisfactory Compliance - This item will be satisfied when the three following criteria are met:
>
> (a) The area is not so contaminated with fecal material that consumption of the shellfish might be hazardous, and
>
> (b) The area is not so contaminated with radionuclides or industrial wastes that consumption of the shellfish might be hazardous (see Section C, Item 7 in the Manual of Operation, regarding toxins in shellfish growing areas), and
>
> (c) The coliform median MPN of the water does not exceed 70 per 100 ml., and not more than 10 percent of the samples ordinarily exceed a MPN of 230 per 100 ml. for a 5-tube decimal dilution test (or 330 per 100 ml. where the 3-tube decimal dilution test is used) in those portions of the area most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions. (Note: This concentration might be exceeded if less than 8 million cubic feet of a coliform-free dilution water are available for each population equivalant (coliform) of sewage reaching the area). The foregoing limits need not be applied if it can be shown by detailed study that the coliforms are not of direct fecal origin and do not indicate a public health hazard. This MPN value is based on a typical ratio of coliforms to pathogens and would not be applicable to any situation in which an abnormally large number of pathogens might be present. Consideration must also be given to the possible presence of industrial or agricultural wastes in which where is an atypical coliform to pathogen ratio."

Thus, the areas shown on Map 3.5 have been closed because they have not met the above requirements. Due to the fact that there are no known sources of radionuclides or industrial wastes in the area, the closings are due mainly to coliform levels in excess of the 70/100 ml standard. The source of the coliforms is presumed to be seapage from failed or malfunctioning septic tanks, from domestic waste point sources, from urban runoff or a synergistic combination of these sources. The reason for the closure of the area above Godfrey Branch where there is little or no development is unknown.

In July of 1980, the Shellfish Sanitation Program Office issued a report of a sanitary survey of the White Oak River Area D-3 covering the sampling period of January, 1979 to June, 1980. The report noted that improvements have been made in the area resulting in the opening of some 600 acres of previously closed shellfish waters in the lower estuary. Most of the improvement was attributed to the operation of the new wastewater treatment facility at Swansboro. The report went on to conclude that unsatisfactory results were still being obtained from sampling stations between Jones Island and Stevens Creek (see Map 3.5). However, it was expected that this area would continue to improve because of the new wastewater treatment 'acility and the abandonment of the old discharge.

3.8 Sources of Pollution

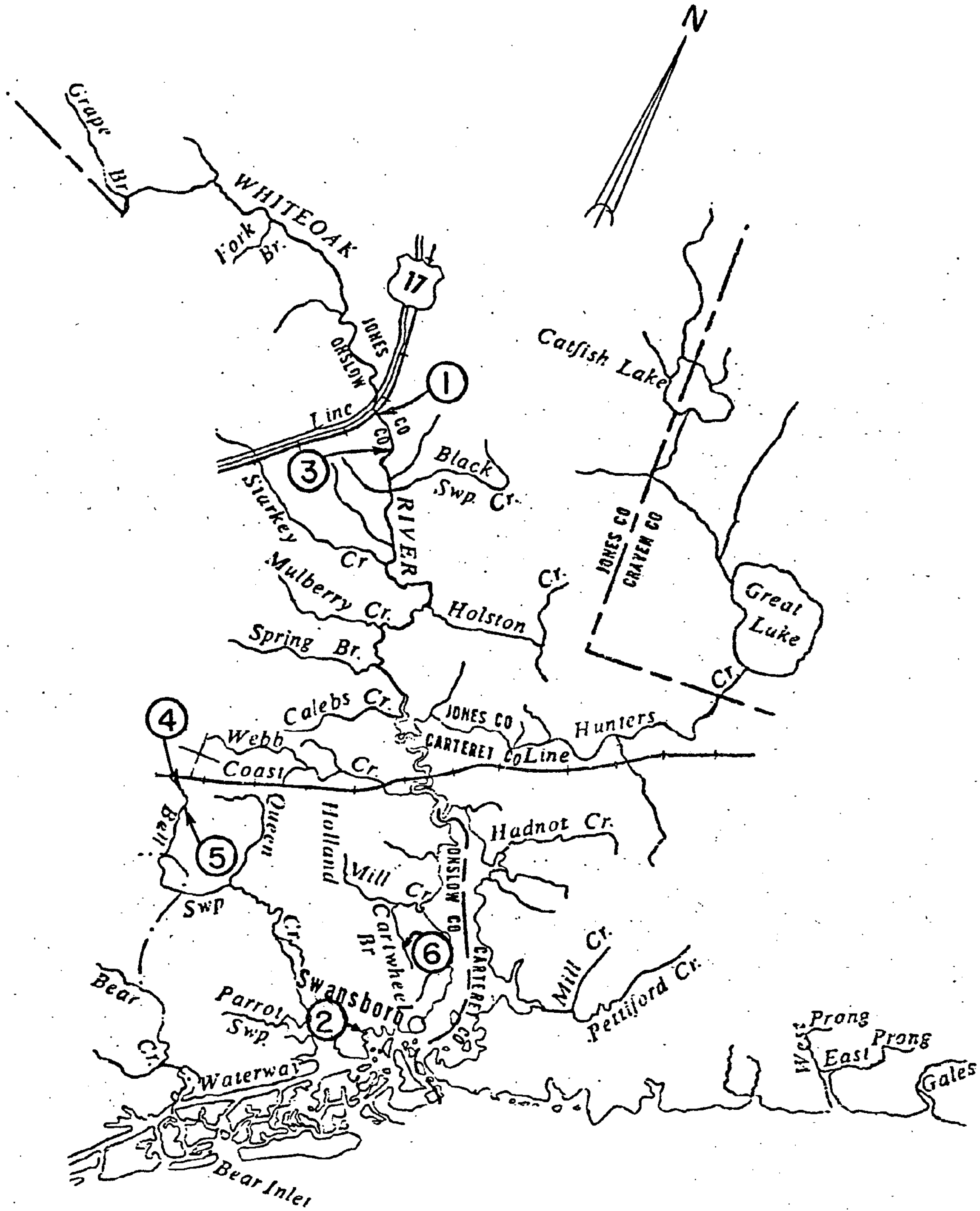
3.8.1 Point Sources of Pollution

The Water Quality Management Plan, White Oak River Basin published by the N. C. Environmental Management Commission in 1975 identifies the point sources of pollution in the White Oak River System. Table 3.3 lists the sources and Figure 3.2 shows the locations of the discharges. All of the major dischargers are in compliance with State regulations and are considered by NCDEM to be providing adequate treatment of wastes. If all the sources were to discharge the maximum volume of treated effluent as specified in their permits, a total of 1.43 MGD could be discharged to the river system. However, the average daily discharge is more likely to fall in the range of 50 to 75 percent of the maximum (0.72 to 1.1 MGD).

TABLE 3.3

Point Sources of Pollution
White Oak River Basin

Figure 3.2 Key No.	Source	Location	Maximum Discharge Volume (MGD)	Lat./Long. of Discharge	Receiving Stream	Status
A. Municipal Facilities						
(1)	Maysville WWTF	Maysville	0.18	34°53'30" Lat. 77°13'50" Long.	White Oak River 1,200 Ft. S. of Hwy. 17 BR.	Adequate
(2)	Swansboro WWTF	Swansboro	0.30		Foster's Creek Tributary to A.I.W.W.	Adequate
B. Industrial Facilities						
(3)	Martin Marietta Aggregates Quarry (gravel washing) Facility	Belgrade	0.81	34°52'12" Lat. 77°13'35" Long.	White Oak River 3/4 Mi. E. of Belgrade	Adequate
C. Private Facilities						
(4)	Gatlin-Ramsey Trailer Park WWTF	Hubert	0.09	34°43'05" Lat. 77°16'00" Long.	Bell Swamp 1/2 Mi. above Hwy 24 Crossing	Adequate
(5)	Hewitt Trailer Park WWTF	Hubert	0.03	34°43'00" Lat. 77°15'40" Long.	Bell Swamp 1/4 Mi. above Hwy 24 Crossing	Adequate
(6)	Swansboro High School WWTF	Swansboro	0.02		U.T. of Cartwheel Br.	Facility to be abandoned & connected to the Swansboro Sewer System
Maximum Potential Total Discharge Volume (MGD)			1.43			



SOURCE: WHITE OAK RIVER WATER QUALITY MANAGEMENT PLAN. (1975)

FIGURE 3.2
POINT SOURCES OF POLLUTION
WHITE OAK RIVER SYSTEM.

3.8.2 Non-Point Sources of Pollution

3.8.2.1 General

Non-point or diffuse sources of pollution include urban stormwater runoff, silvicultural and agricultural runoff and residuals from individual septic tanks, etc. These sources have not been quantified to the same degree as have been the point source discharges within the basin. However, some estimates of their magnitude and influence have been made.

3.8.2.2 Stormwater Runoff

Water pollution originating from stormwater runoff from urbanized or developed areas is recognized as a complex problem which has been only partially solved. Whenever it rains, the streams in the White Oak River Basin receive a variety of pollutants including heavy metals, chemicals, sediment, litter, residual oils and bacteria. The stormwater flows across streets, parking lots, rooftops, lawns, and gutters carrying pollutants directly to waterways without treatment. The urban and built-up areas shown on Map 3.2 would be most likely to contribute such pollutants to the White Oak River. The Maysville - Belgrade area in the upper river basin and the Swansboro - Cedar Point area in the lower estuary would be the major generators of stormwater runoff. It is suspected, but not confirmed, that higher coliform counts occur in the local receiving waters near these areas immediately after periods of heavy rain. Such runoff is probably a contributing cause of the closing of shellfishing waters as indicated in Map 3.5.

The N. C. State-Wide 208 Area Management Plan, Water Quality and Urban Stormwater, indicates that nationwide research on the stormwater problem has been considerable but information on the effectiveness of controls is still rudimentary. The Plan recommends certain practices that can benefit water quality along with serving other beneficial purposes such as flood control. The recommended practices include street cleaning, catch basin cleaning, covering chemical stockpiles, use of small-scale detention basins and infiltration methods, erosion control, litter control, and protection of flood plains.

3.8.2.3 Agricultural Runoff

Another source of surface water pollution is agricultural runoff. The magnitude of this source depends upon the frequency and duration of intense rainfalls. The agricultural activities that are most likely to cause pollution and/or affect water quality include:

(1) The use of fertilizers, pesticides, and herbicides on row crops and pastures,

(2) Pollution from farm animals, especially livestock and poultry,

(3) Pollution originating from farm based septic tanks used for the disposal of domestic wastes, and

(4) Exposure of the land to erosion during the cultivation of fields and land clearing for buildings, roads, or other developments.

The first three items are expected to increase the concentrations of substances dissolved in water leaving the basins. The last item is expected to increase concentrations of suspended sediment and constituents adsorbed on or in some way associated with sediment.

The Department of Natural Resources and Community Development, Division of Environmental Management's Water Quality Management Plan for the White Oak River Basin (Sub-Basin-01) estimates that the pollution loading from agricultural runoff is on the order of 1841 pounds of BOD_5 per day. The rainfall frequency in this area averages one significant rainfall event (one inch or more) every thirty days. The pollutional loadings from one of these events can be estimated from the size of the drainage area and using a conservative runoff coefficient of 0.2. The calculation is as follows:

Drainage Area = 400 square miles = 11,151,360,000 square feet.

Volume of runoff resulting from a one-inch rainfall event =

(0.2) (1/12 ft.) (11.15136 b.l.sq.ft.) = 185,856,000 cubic feet = 1,390 MGD

Waste Load = (30 days) x (1,841 pounds BOD_5/day) = 55,230 pounds BOD_5

Waste Concentration = 39.73 pounds BOD_5 per million gallons = 4.76 milligrams per liter.

The pollution load associated with surface runoff in terms of BOD_5 appears to be relatively less significant than point sources within the sub- basin.

A recent study of the environmental effects of agricultural land development on the drainage waters in the N. C. tidewater region was completed by the Agricultural Research Service.[1./] While this study focused mainly on the development of the high organic soils in Dare, Hyde, Tyrrell and Washington Counties of N. C., some of the findings are pertinent to this study on the White Oak River Basin:

(1) Peak runoff rates occur earlier and are three to four times higher on developed lands than on similar undeveloped lands.

(2) The largest potential eutrophication hazard resulting from development may be the increase in phosphorus in drainage waters. The effect of development upon phosphorus losses in drainage waters is very dependent upon soil type. Inorganic soils react with fertilizer phosphorus to prevent its loss. The solubility of phosphorus in shallow and deep organic soils is much greater than in inorganic soils, so much of the added phosphorus can be lost to drainage water. The weighted average concentration in drainage waters from the two developed organic soils was 1 - 2.5 mg/l for a total phosphorus efflux of 7 - 10 kg/ha/yr. The amount of this phosphorus which reaches major streams or estuaries

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1./ Skaggs, R.W., etal. (August 1980). Effect of Agricultrual Land Development on Drainage Waters in the North Carolina Tidewater Region. Water Resources Research Institute Report No. 159, Raleigh, N. C.

will depend on distance the water must travel to reach the outlet, the type of sediment in the collector ditches, and the soil material in the banks. If the sediments are from inorganic soils or the canals are cut into mineral layers, much of the inorganic orthophosphate may be removed from solution by these sediments. Fortunately, much of the current agricultrual development is on mineral soils where P losses are small. However, it should be recognized that agricultural development of organic soils low in mineral content immediately adjacent to estuaries or major streams will very significantly increase the entry of phosphorus into these waters.

(3) The highly organic blackland soils are very flat so erosion is not a problem, but development does cause a small increase in the sediment load of drainage waters. This increase is particularly apparent during the developmental phase of farming. Turbidity of the drainage water is increased during clearing and land shaping. Once initial development is completed, erosion and turbidity during normal agricultural production is not likely to cause a water quality problem.

(4) There are several water quality parameters which are measurably affected by development, but the change is relatively small. For example, D.O., BOD, temperature, and pH, are all slightly higher in drainage water from developed areas. Other parameters which change upon development but are not generally considered critical in evaluation of water quality in this region are Ca, Mg, Cl, Na, and K. There is very little effect of development upon efflux of the metals Cu, Zn, and Fe.

(5) One potential problem with development of the organic soils for pastures near shellfishing waters is the loss of fecal organisms in drainage waters. The counts of fecal and total coliform bacteria in drainage water from the pastured site were considerably greater than from natural waters. This

increase in coliform bacteria from grazed lands is common throughout the U.S. and apparently causes few problems. However, a problem could result if grazed land is located immediately adjacent to shellfish waters. Development also caused an increase in coliform bacteria from the cropped shallow organic soil even though no domestic animals were ever kept on this site.

(6) Concentrations of the herbicide alachlor in drainage water after application suggested that some applicators were careful to avoid spraying the V-ditches draining the fields but that some may have sprayed directly over them, or so close that heavy drift of sprays occured, causing excessively high concentrations of herbicide in drainage water during the first few days after some applications. More diligence and care during application of all pesticides used on many farms in the Tidewater Region of North Carolina, where ecologically sensitive areas exist in close proximity to large agricultural areas, would reduce or even eliminate significant hazards caused by direct spraying of, or drift onto water in drainage canals.

(7) Transport of the herbicide alachlor and probably other pesticides as well in surface runoff from the high organic soils of the Tidewater Region of eastern North Carolina and similar areas elsewhere does not appear to pose a significant hazard to aquatic life. However, it appears that some hazard from overspraying of or drift into drainage ditches exists in ecologically sensitive areas which the experimental sites represent. Most likely, more diligence and care during application would greatly reduce such hazards.

Beginning in 1977, the N. C. Division of Marine Fisheries with the cooperation of the N. C. Office of Coastal Management began a study of the effects of upland drainage on the estuarine nursery areas of Pamlico Sound. The results of this study are pertinent to the White Oak River estuary.

The N. C. Division of Marine Fisheries established four sampling stations in tributaries of northern Pamlico Sound, N. C. The four stations received either heavy, moderate or no drainage through man-made water courses. The period of study was from 1977 to 1980. The following conclusions were derived from the study.:

(1) Drainage of surface water from upland areas into nursery areas through man-made ditches and canals creates unstable salinity conditions when rainfall exceeds one inch in a 24-hour period. The unaltered nursery areas showed much more stable salinity readings during the same rain periods.

(2) The nursery areas appear to have the capacity to receive a certain amount of "unnatural" drainage and buffer the effects of rainfall on salinity, except during periods of extended rain.

(3) Extensive drainage into a single nursery area reduces its value as estuarine habitat by reducing average salinities and making it more sensitive to the effects of rainfall within the drainage basin.

(4) Relative productivity of estuarine organisms (brown shrimp and juvenile finfish) was lower each year in the nursery area with extensive drainage.

(5) The data did not show that there were any mass or complete movements of juvenile brown shrimp from the nursery areas as a response to rapid changes in salinity readings. The most serious effects of drainage into nursery areas appear to be the degree of alteration and the danger that alteration will be severe enough to create an unsuitable habitat during periods of normal rainfall.

In recognition of the appeal and value of the seafood resources derived from the estuarine areas and the fact that changing uses of lands surrounding vital nursery areas is inevitable, given the current trends in the value of agricultural and recreational developments, the Division of Marine Fisheries made the following recommendations:

(1) It is important that resource agencies stress the value and fragile nature of small estuaries and encourage development of adjacent lands in such a way as to minimize its adverse impacts.

(2) Identification of critical nursery areas must be made and protection of these areas enhanced with proper legislation. Local, state, and federal agencies should develop joint comprehensive programs which will allow the wisest use of coastal lands and minimize degradation of water quality and wetland habitat.

(3) Particular attention should be placed on developing drainage programs which promote: (a) strict controls over construction of new drainage systems discharging into critical nursery areas; (b) maintenance of existing ditches and canals during periods of least biological activity in the receiving waters; (c) analysis of the hydrologic and biological impacts of expanding existing drainage systems; (d) development of water management and water control schemes which limit discharge points, and (e) consideration of the cumulative effects of extensive alteration of small estuaries.

3.8.2.4 Silvicultural Runoff

Due to the large percentage of land in the White Oak River Basin devoted to forests (see Map 3.4 and Table 3.2, above), silvicultural activities (harvest of trees) could have a significant impact on water quality in the White Oak River Basin. However, the pollution potential of these activities are perhaps the least studied and understood of all of the non-point sources of pollution in the White Oak River Basin. The mechanical methods of harvesting timber have an obvious adverse effect on vegetation and the land with potential for adverse impacts on water quality. The State's Water Quality and Forestry Management Plan (see Bibliography) identifies the following areas in which additional information is needed:

(1) The impact of intensive mechanical site preparation activities on water quality of receiving streams.

(2) Acceptable alternatives to intensive mechanical site preparation such as the use of herbicides and/or controlled fire.

(3) The frequency and degree of use of measures to protect water quality during timber harvesting and site preparation activities.

(4) The extent to which forest management plans are requested and prepared early enough prior to harvesting to include recommended water quality protection measures.

(5) The extent to which the recommendations in forest management plans are followed.

(6) The water quality management impact of draining wetlands for intensive forest management in the coastal plain region.

However, despite the prevalence of many unknowns in this area, the Division of Forest Resources of the N. C. Department of Natural Resources and Community Development has independently developed a set of forest practice guidelines related to water quality (see Bibliography, Section 8). The guidelines cover logging, site preparation and the use of pesticides, fertilizers and fire retardants. The extent to which these guidelines are or are not being followed in the White Oak River Basin is unknown.

3.8.2.5 Septic Tank Effluent Pollution

Another source of non-point or diffuse pollution is from on-site wastewater disposal systems, mainly from septic tanks. The State of N. C. has conducted limited monitoring of suspected problem areas and site investigations in order to define current water quality problems caused by septic tanks. As a part of the development of the State 208 Plan, the coastal area around Wilmington, N. C. was selected for monitoring by virtue of having high septic tank densities adjacent to shellfish waters. Monitoring was peformed on four tidal creeks emptying into the Atlantic Intracoastal Waterway in this area. The creeks have no point source discharges. Residential development on these creeks ranged from heavy (Whiskey and Bradley Creeks) to almost non-existent (Futch Creek). Bacteriological (total and fecal coliform) samples were obtained from these creeks during the period of July to October, 1978. The test results along with density and soil factors which might be expected to affect coliform levels are shown in Table 3.4 following this page. The following conclusions were made as a result of these findings:

(1) As the intensity of unsewered residential development in the area increases, both total and fecal coliform counts in the creeks rise. The highly developed Whiskey and Bradley Creek watersheds exhibited fecal counts far higher than the undeveloped watershed (Futch Creek). Total coliform counts in Whiskey and Bradley were respectively 60 and 40 times higher than those observed in Futch Creek.

(2) Residential development in the area has historically occured in watersheds containing the largest percentages of soils which are severely limited for septic tank installations.

(3) An apparent dichotomy appearing in the data for Whiskey and Bradley Creeks (a much higher septic tank density in the latter, accompanied by no

TABLE 3.4

Results of Monitoring of Tidal Creeks
In New Hanover County, North Carolina[1/]

	Whiskey Creek	Bradley Creek	Pages Creek	Futch Creek
Fecal Coliform* (colonies/100 ml)	196	228	64	21
Total Coliform* (colonies/100 ml)	3970	2452	2007	66
Estimated Septic Tank Density** (units/acre)	.367	.563	.154	.036
Soils with Severe Limitations for Septic Tanks*** (percentage of basin)	78	70	47	10

1./ Source: North Carolina Department of Natural Resources and Community Development. July 1979. Water Quality and On-Site Wastewater Disposal, a Management Plan. Raleigh, N. C.

* Mean values determined by disregarding the high and low value samples.

** Estimate based on data from Wilmington-New Hanover Planning Commission map of dwelling units in New Hanover County, drawn from 1975 aerial photos.

*** Estimated from detailed soils map of New Hanover County, U.S. Soil Conservation Service.

appreciable rise in mean coliform counts) may be related to the fact that development in the Whiskey Creek watershed is concentrated more closely to the creek itself.

(4) A much more elaborate study would be necessary to determine definitively that septic tanks are the cause of the pollution observed. However, the fact that all residences in the area are served by septic tanks tends to support the hypothesis that the pollution is related to septic tank usage.

In view of the above, it can be reasonably concluded that septic tanks are definitely a contributing factor to the closing of certain areas of the White Oak River to shellfishing and are a source of surface water pollution.

3.9 Fisheries Resources

Several studies of the fisheries resources of the White Oak River have been completed in recent years. In 1964, the Division of Inland Fisheries of the N. C. Wildlife Resources Commission conducted a survey of the White Oak River in order to determine basic reference data on the biological, chemical and physical characteristics of the streams in the watershed. The physical and chemical characteristics of the streams within the White Oak River watershed were found to vary considerably from the headwaters to the coastal area. Generally, the waters were found to be relatively free from pollution and chemically suitable as fish habitat.

The dissolved oxygen concentrations varied from 1.0 ppm to 8.0 ppm. The lower concentrations invariably were found in streams containing intense swamp drainage. Generally, the concentrations of dissolved oxygen were adequate for the fish life present.

The chloride content (ppm NaCl), expressed as chlorinity, ranged from 0.0 ppm in the strictly fresh-water habitat to 29,250 ppm in the marine habitat.

Lunar tides, which affect approximately 70 percent of the water area, are constantly changing the fresh-water habitat, and particularly during extremes associated with severe storms and hurricanes. During the study, the transition zone between fresh- and salt-water habitats appeared to be a fairly well defined area, usually with only two to three miles separating the upper and lower limits. The transition zone between the fresh- and salt-water habitat is shown in Figure 3.3.[1]

The fresh-water fish habitats are typical black-water, swamp-drainage streams usually with an imperceptible flow, sand-detritus bottom, and very little turbidity. Most of the small streams are choked with fallen trees and overhanging bushes. The lower coastal reaches of the watershed are typically marine habitat and support an important shellfish, sport-fish, and food-fish industry.

The more important fresh-water game species found during the survey, listed in decending order of their frequency of occurance, were:

Redfin pickerel	Esox americanus americanus
Chain pickerel	Esox niger
Warmouth	Chaenobryttus gulosus
Bluegill	Lepomis macrochirus
Pumpkinseed	Lepomis gibbosus
Redbreast sunfish	Lepomis cyanellus
Largemouth bass	Micropterus salmoides
Mud sunfish	Acantharchus pomotis

The more important fresh-water non-game species found during the survey, also listed in decending order of their frequency of occurance:

1./ Recent studies of sediment cores by UNC scientists, Martens and Goldhaber (see Bibliography, Section 8), indicate that seawater influenced sediment chemistry farther upstream in the past than at present.

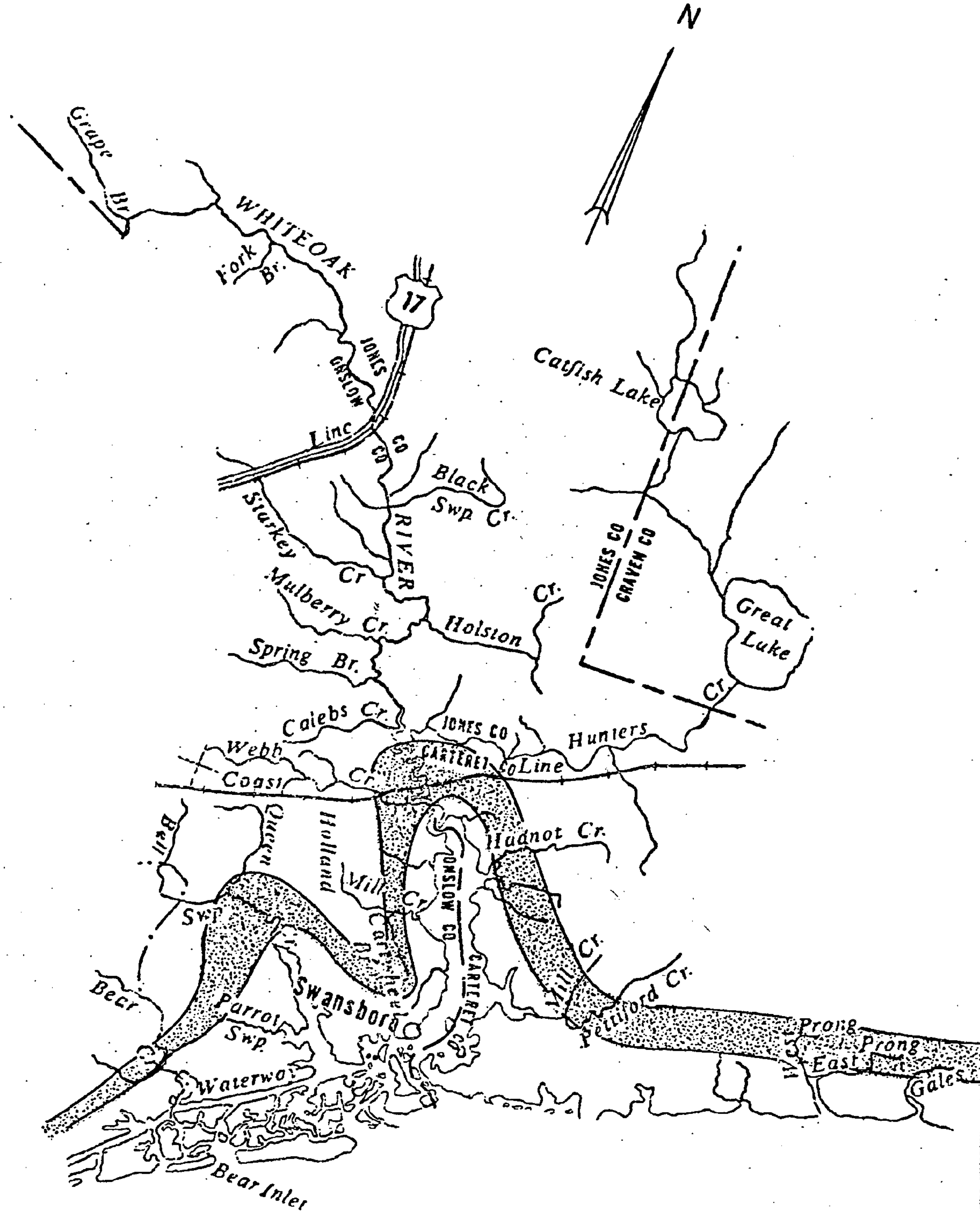


FIGURE 3.3

WHITE OAK RIVER BASIN
TRANSITION ZONE BETWEEN
SALT AND FRESH WATER.

SOURCE: SURVEY AND CLASSIFICATION OF THE NEW - WHITE OAK - NEWPORT RIVERS AND TRIBUTARIES, N. C. 1965
WILDLIFE RESOURCES COMMISSION
RALEIGH, N. C.

KEY:

TRANSITION ZONE

Banded sunfish	Enneacanthus obesus
Pirate perch	Aphredoderus sayanus
Bluespotted sunfish	Enneacanthus gloriosus
Golden shiner	Notemigonus crysoleucas
Ironcolor shiner	Notropis chalybaeus

Some of the more important salt-water species collected during the survey are listed in phylogenetic order as follows:

American shad	Alosa sapidissima
Atlantic menhaden	Brevoortia tyrannus
Bluefish	Pomatomus saltaltrix
Spotted seatrout	Cynoscion nebulosus
Spot	Leiostomus xanthurus
Atlantic croaker	Micropogon undulatus
Black drum	Pogonias cromis
Red drum	Sciaenops ocellata
Striped mullet	Mugil cephalus
Summer flounder	Paralichtys dentatus
Southern flounder	Paralichtys lethostigma

The dominant freshwater predator species collected in the watersheds were the redfin and chain pickerel.

The fish populations were generally well balanced with a relatively high ratio of game to non-game fishes. This ratio was attributed to several factors: High water quality, good physical habitat, and low fishing pressure.

Detailed assessments of each of the major tributaries of the White Oak River are found in the apendicies to the study (see Bibliography) which is available from the Wildlife Resources Commission.

From October, 1973 to June, 1975, the N. C. Division of Marine Fisheries conducted a survey of anadromous fisheries of the White Oak River System. This study identified a total of six anadromous species which enter the White Oak River including the Striped bass (Morone saxatilis), American shad (Alosa sapidissima), Hickory shad (A. mediocris), blueback herring (A. aestivalis), alewife (A. pseudoharengus), and Atlantic sturgeon (Acipenser oxyrhynchus). All six species are considered both sport and commercial fish and are taken by standard commercial fishing gear. The objectives of the Marine Fisheries' study was to determine the distribution of migrating and spawning adult anadromous fishes, to determine spawning areas and periods of major spawning activity for anadromous species, to determine nursery areas, and the growth and movements of juvenile anadromous fishes. The Marine Fisheries' researchers found that the White Oak River supports a substantial run of blueback herring and smaller runs of alewife, American shad, and hickory shad. Adult blueback herring were found to enter the river in January. Juvenile blueback herring were subsequently found to use the Martin Marietta Belgrade Quarry Lakes, the river below, and certain tributaries as nursery grounds. Their seward migration was found to occur in October.

Adult alewife were found to enter the river in April. Only a few juvenile American shad were found.

All three species of anadromous fish used the Martin Marietta Belgrade Quarry Lakes as spawning areas during April and May. Although the lakes represent an altered environment, they still appear to support adequate populations of anadromous fish. In addition, in 1975, river herring were found to use Holston and Grant Creeks as spawning areas with spawning probably occuring in Hunter and Webb Creeks.

SECTION 1

EXECUTIVE SUMMARY

WHITE OAK RIVER SYSTEM STUDY

(A Plan Of Action For The White Oak River)

HENRY VON OESEN AND ASSOCIATES
CONSULTING ENGINEERS
AND PLANNERS

SECTION 1: EXECUTIVE SUMMARY

A study of the White Oak River basin was conducted to define existing conditions and problems and to suggest recommendations for further study along with proposed non-structural and structural solutions to identified problems. Also included herein is a plan of action for the White Oak River wherein each specific recommendation is identified and estimated costs are suggested for completion of the recommendation. While certain identified problems must receive additional study, some actions can be undertaken immediately with little or no additional delay.

The first major conclusion of this study is that the water depths in the lower White Oak River have decreased during the past century and particularly since the major construction projects of the AIWW and N.C. Route 24 Bridge and Causeway which occured in the early 1930's. The redistribution of unconsolidated spoil materials from the dredging of the AIWW to the area above the N.C. 24 Bridge/Causeway is considered to be a major cause of this major shoaling and depth loss problem in the lower estuary. The construction of the bridge and causeway reduced the effective width of the river, blocked off one channel of the river, and presumably acted to contribute to the shoaling problem.

A second major conclusion derived is that many of the seafood resources in the White Oak River are apparently underutilized. Pollution from septic tank effluents and other non-point sources have contributed to this underutilization by placing vast areas of productive shellfish bottoms off limits to commercial fishermen. While an oyster replanting program conducted by the N.C. Division of Marine Fisheries has been successful, a similar program for relaying of polluted clams has not been attempted due to a lack of funds and the restraints imposed by current fisheries regulations. Aggressive initiatives on the part of responsible individuals and agencies will be required to fully exploit the fisheries resource potentials of the White Oak River Basin.

In recognition of these problems, the following plan of action is recommended for the White Oak River:

A. Overall River Basin Management and Control

(1) A study to be conducted under the UNC-Sea Grant Program to develop a mathematical model of the White Oak River Basin with the goal of predicting future changes and abating pollution.

(2) A reactivation of the PL 83-566 Watershed Project on the White Oak River administered by the USDA-SCS with the goal of developing a comprehensive watershed plan.

(3) Improvement of existing agricultural, silvicultural and septic tank installation practices throughout the White Oak River Basin.

B. Fisheries Resources

(1) A shellfish bottom survey of the White Oak River Estuary to be conducted by the N. C. Division of Marine Fisheries.

(2) A new management regulation to be developed by the Marine Fisheries Commission to permit relaying of clams from polluted to clean areas for self-cleansing and subsequent marketing.

(3) An expansion of the shellfish relaying program conducted by the N.C. Division of Marine Fisheries in the White Oak River by greater utilization of private contractors.

(4) A continuation of a study of the stunted oysters in the White Oak River by the Duke University Marine Laboratory.

C. Sedimentation: An expansion of the existing Bogue Inlet study conducted by the Wilmington District of the U.S. Army Corps of Engineers to include investigation of shoaling and the effect of canalized flows in the lower White Oak River estuary.

The Marine Fisheries study concluded that the greatest problem facing anadromous fish populations in small rivers like the White Oak is flood control activities such as channelization and watershed development. The impact of such alterations has been seen in the case of the New River which once had a significant anadromous fish population prior to a significant channelization project for flood control above Jacksonville. As a result, the N. C. Division of Marine Fisheries recommends that future channelization projects be given close scrutiny, especially where anadromous fish resources are involved.[1/]

Discussions held with Mr. Bob Chapoton of the National Marine Fisheries Service (NMFS) in Beaufort, N. C. revealed that the White Oak River is an important nursery area for juvenile Atlantic menhaden. Menhaden are spawned in the ocean and enter the White Oak River estuary as larvae from November to May. Once strong enough to swim against the tidal currents, they move upstream towards fresh water where they transform into juveniles by mid-May. They remain in the estuary for their first growing season, gradually moving down stream in the summer and reaching the lower estuary or open sea by autumn.

Menhaden are very important economically to North Carolina. Menhaden are processed into fish oils and meal for agricultural feed supplements. The menhaden are harvested in the nearshore ocean waters after they migrate to the ocean via Bogue Inlet. The NMFS reports that the White Oak River exceeds the Cape Fear River in importance as a nursery for menhaden.

1/ Martin Marietta aggregates recently received CAMA and Corps permits for the proposed construction of a 90-foot wide, 45-50 foot long fill roadway crossing the White Oak River at their Belgrade, N. C. quarry. As proposed, approximately 1,000 cubic yards of clay will be placed below the normal water level contour elevation for the crossing which is located immediately downstream from the existing quarry lakes. Three 90-foot long, 12-foot diameter culverts are to be emplaced in the river channel to accomodate normal and 25-year flood flow requirements.

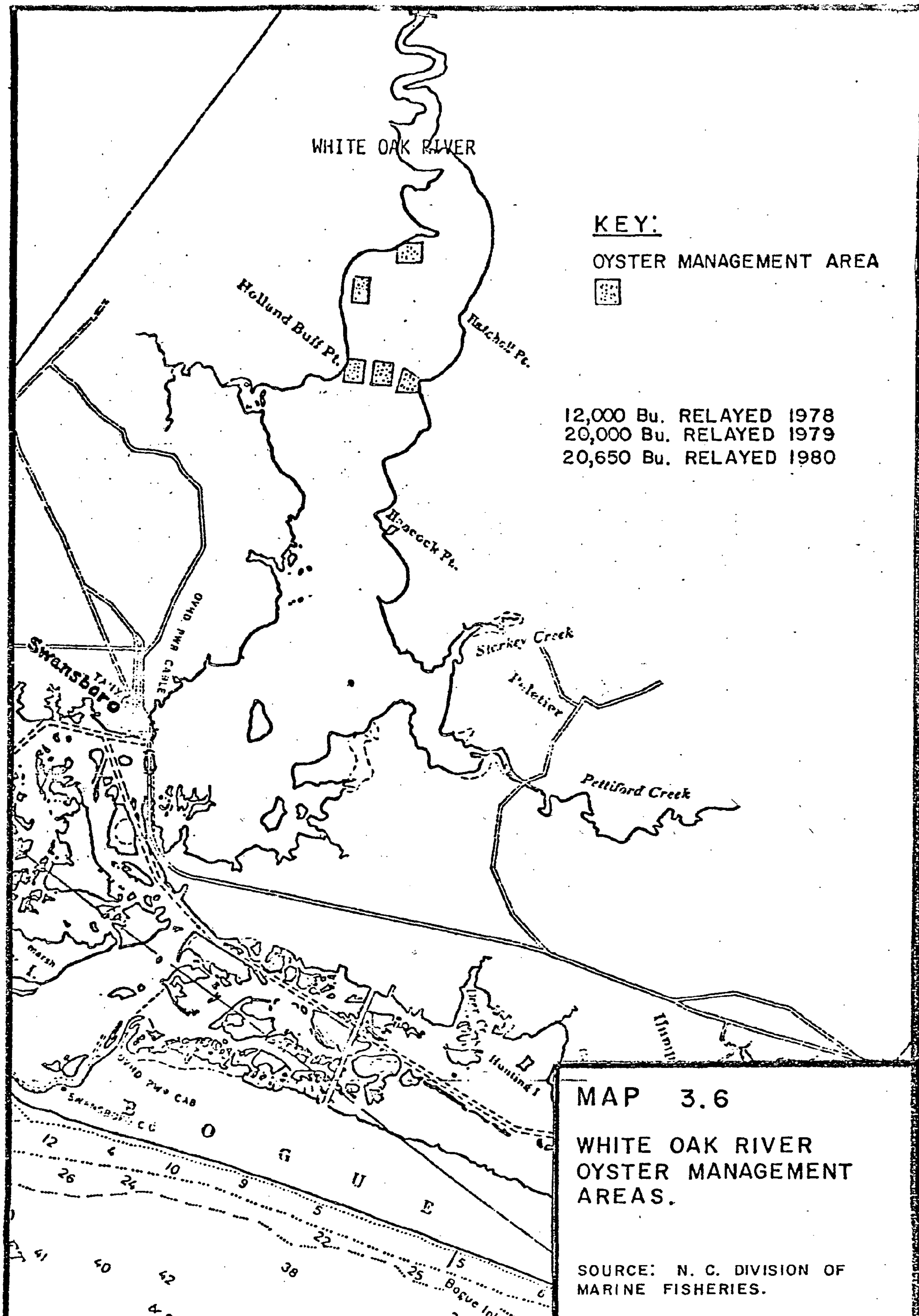
In addition to finfish resources, the White Oak River is very important as a productive area for shellfish, mainly oysters and clams. The N. C. Division of Marine Fisheries (NCDMF) is of the opinion that the resource is considerable. However, to date it has not been quantified by means of a shellfish bottom survey. Since 1972, the NCDMF has conducted a very successful, oyster relaying project in the upper river estuary. Oysters are relayed from over crowded oyster bars in mid river and emplaced in public oyster management areas. Map 3.6 shows the locations of the public oyster management areas and the quantities of oysters which were relayed in the years 1978, 1979 and 1980. These public areas are opened and closed by proclamation.

In addition to oysters, clams are another important shellfish resource in the river. At present, the river is opened to clamming all year long except for the areas closed due to pollution (see Map 3.5). Significant clam resources are found in the closed areas. However, lack of funds and existing regulations have hindered any efforts to relocate these to non-polluted areas for self cleansing and ultimate marketing. (See Section 5.2.2 for a further discussion of this matter).

3.10 Seafood Landings

The N. C. Department of Natural Resources and Community Development, Division of Marine Fisheries has kept records on the pounds and value of the seafood which has been obtained from the White Oak River system since the year 1959. However, the data prior to the year 1978 is often sketchy and incomplete making an accurate analysis difficult, if not impossible. Nevertheless, despite the difficulties with the data base, overall trends can be noted.

The trends in landings of hard clams, oysters and blue crabs from the White Oak River are shown in Figures 3.4, 3.5 and 3.6, respectively. Up and down fluctuations from year to year are noted in each case. This may be due in part

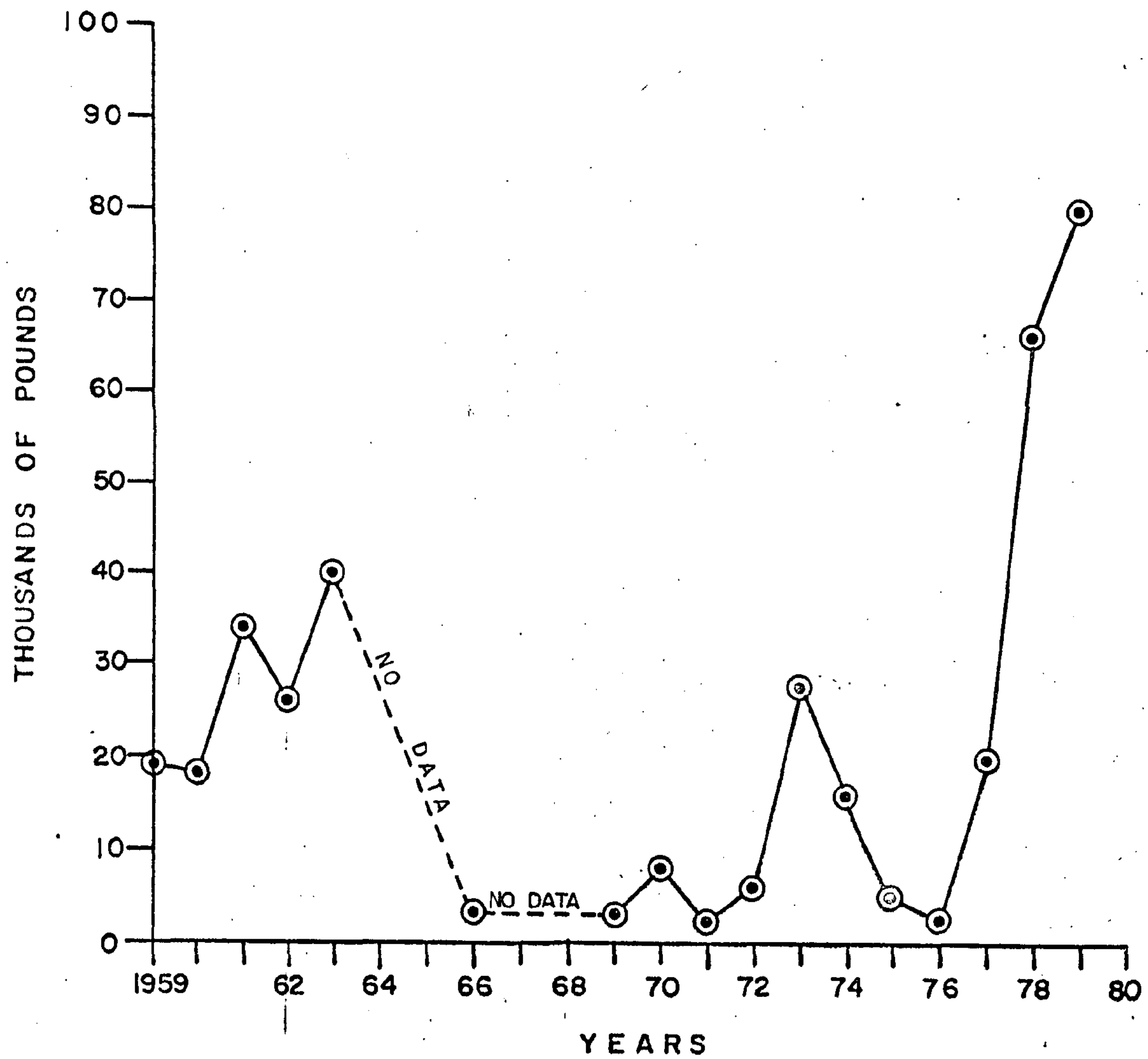


MAP 3.6

WHITE OAK RIVER OYSTER MANAGEMENT AREAS.

SOURCE: N. C. DIVISION OF MARINE FISHERIES.

FIGURE 3.4
WHITE OAK RIVER
HARD CLAM HARVEST (LBS)
1959 - 1979



HENRY VON OESEN & ASSOCIATES - CONSULTING ENGINEERS & PLANNERS - WILMINGTON, N. C.

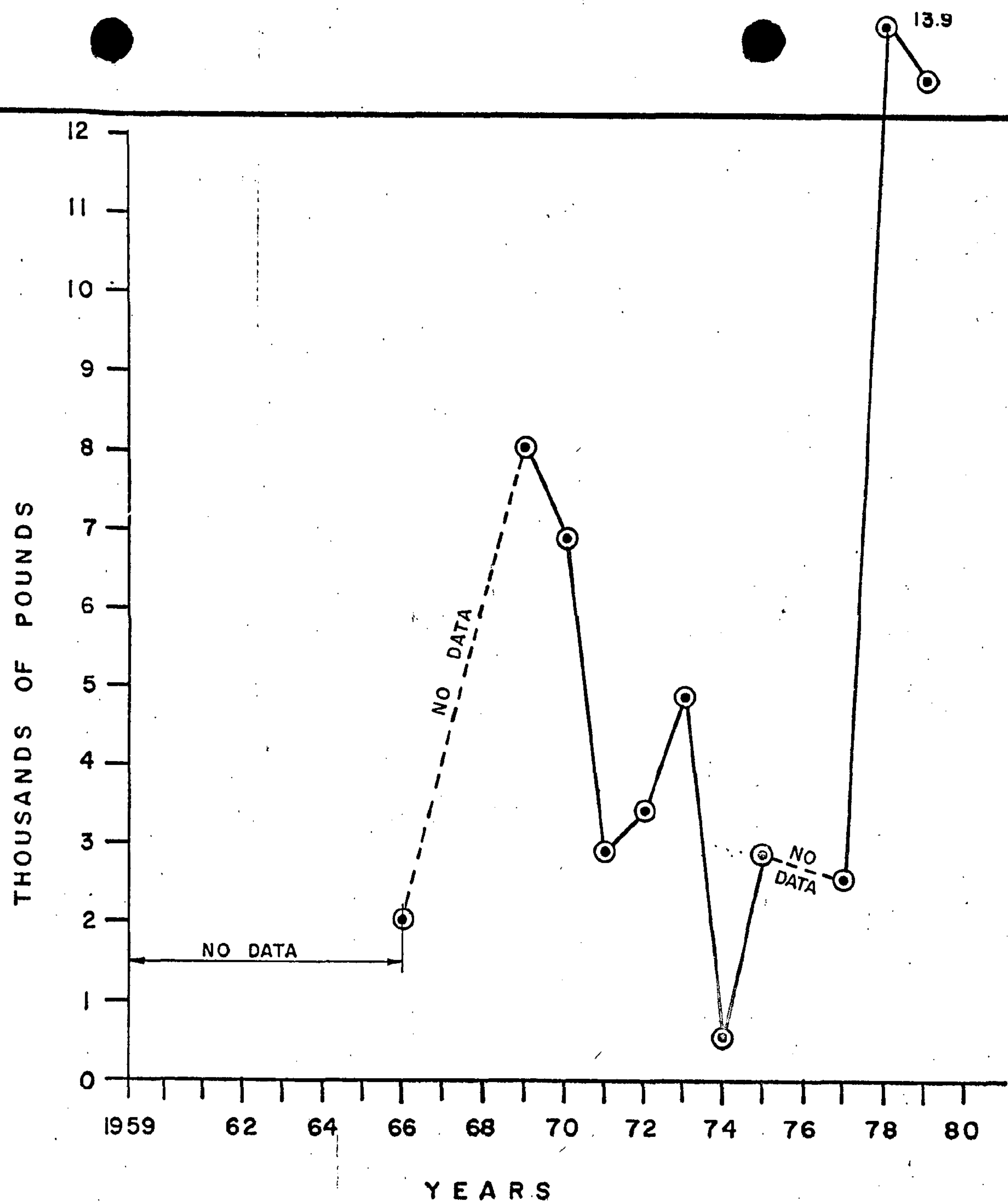


FIGURE 3.5
WHITE OAK RIVER
OYSTER HARVEST (LBS)
1959 - 1979

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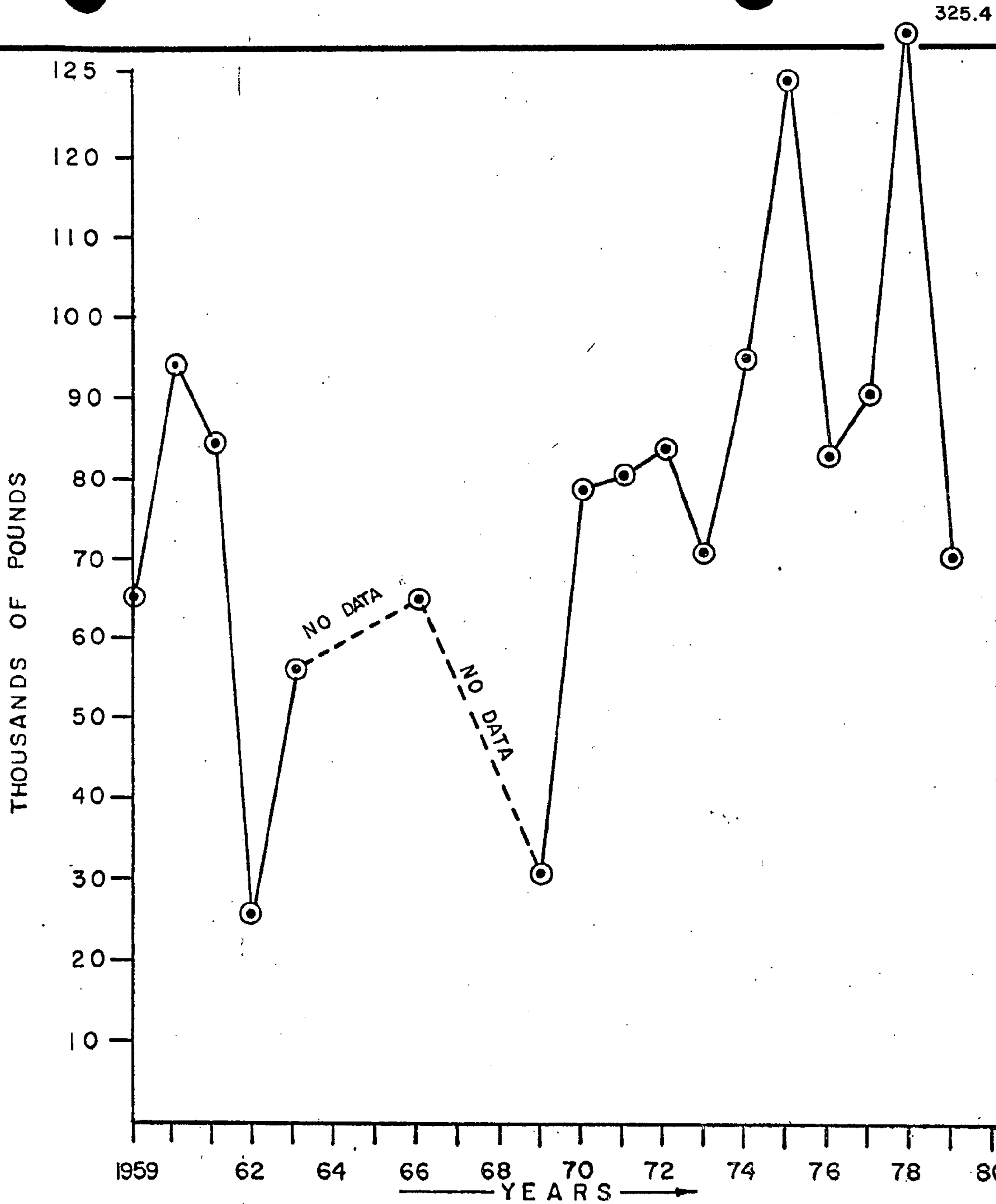

FIGURE 3.6
WHITE OAK RIVER
BLUE CRAB HARVEST (LBS)
1959 - 1979

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to normal biological fluctuations, as well as errors or omissions in data collection or reporting. Data from 1978 to 1979 are to be trusted more than data collected in prior years due to substantial improvements in the data collection program. Landings in recent years appear to be generally greater than those reported in the past. In the case of clams and blue crabs, these increased landings have been attributed to increased effort. In the case of oysters, the increased landings have been attributed to the success of the NCDMF's relaying program (see Section 3.9).

The trends in landings of finfish and shrimp are not as clear due to a lack of data. Finfish landings in 1966 were 3,580 pounds, with 57,300 pounds in 1978 and 112,100 pounds in 1979. These increases appear to be due in part to better reporting and data collection methods. Shrimp landings have fluctuated from 25,795 pounds in 1966 down to a low of 4,100 pounds in 1978 and back up to 19,600 pounds in 1979. Shrimp landing data appear here to reflect the poor biological conditions of the 1978/79 season. Shrimp landings statewide were less than average during both years due primarily to adverse weather conditions (low salinities and low temperatures). However, the NCDMF personnel indicate that shrimp have never been a significant resource in the White Oak River. This is due to the fact that most of the embayments in the river are closed to shrimping because these areas serve as nursery areas for juvenile shrimp. Furthermore, the shrimp in the river tend to migrate from the estuary rapidly. Therefore, most of the White Oak River shrimp are caught in the ocean off of Bogue Inlet and are landed in other ports in the area rather than at Swansboro.

The economic value (dockside value) of seafood derived from the White Oak River approached $315,000 in 1979. Trends are shown in Figure 3.7. The quantum jump in value in 1978 is attributed in part to better data collection and to inflation as well as increased harvests of shellfish from the estuary.

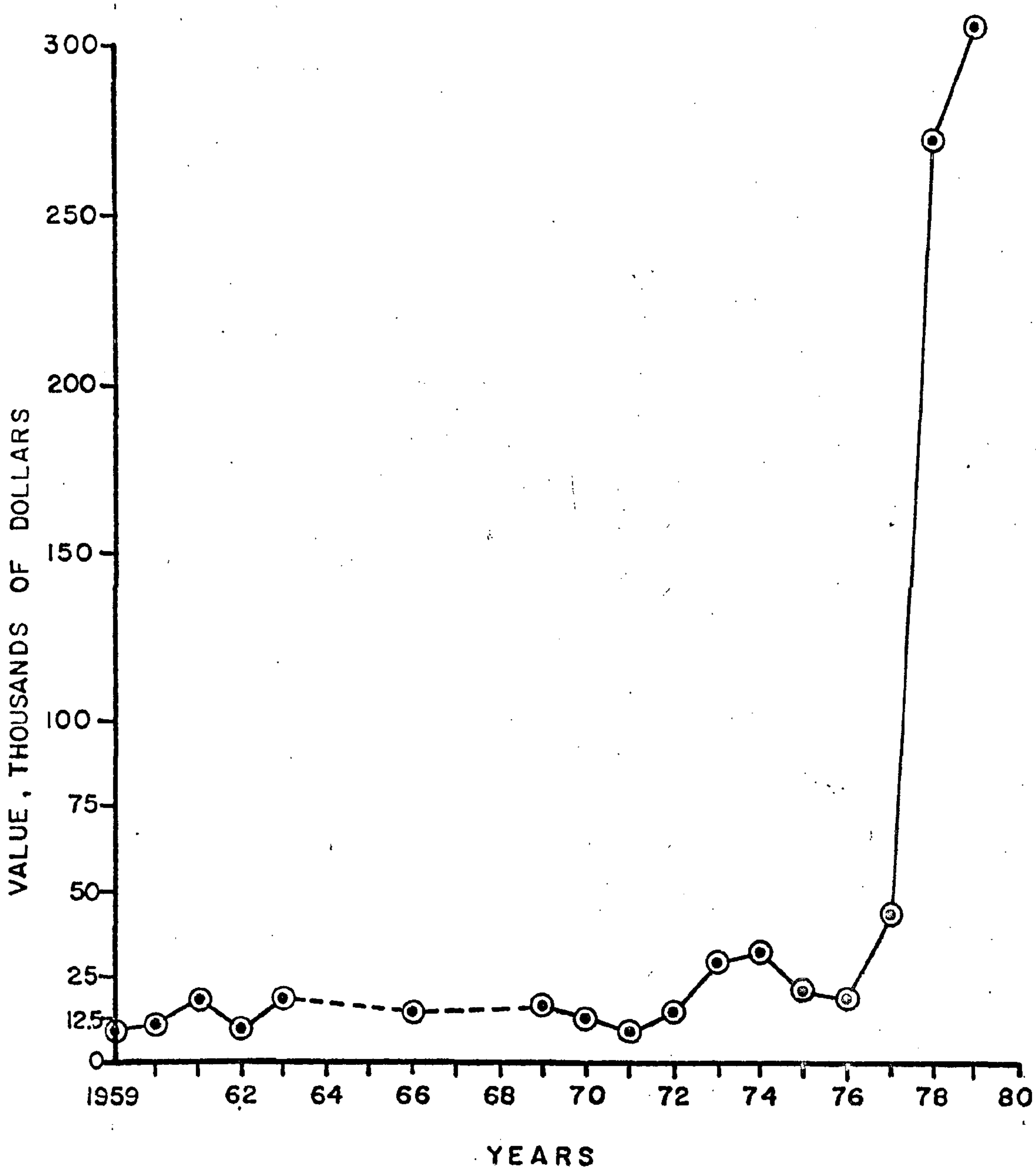


FIGURE 3.7
WHITE OAK RIVER
TOTAL VALUE OF
SEAFOOD LANDED
1959-1979

HENRY VON OESEN & ASSOCIATES - CONSULTING ENGINEERS & PLANNERS - WILMINGTON, N.C.

The dockside value of seafood landed is only a fraction of the final value after it filters through normal marketing channels. Using an economic multiplier of 2.0, the actual value of seafood to the area for the year 1979 is about $630,000.

The data presented here does not reflect a general diminution of fisheries resources from the White Oak River. To the contrary, it appears to show an increase (whether it be contrived or real) in both pounds landed and dockside value. N. C. Division of Marine Fishereis personnel feel that increased effort to harvest seafood is a primary reason for these increases.

SECTION 4: IDENTIFICATION OF EXISTING PROBLEMS

4.1 Sedimentation

4.1.1 General

Pollution, sedimentation and shoaling, particularly in the lower river estuary, have been identified by the White Oak River Advisory Council as the key problems to be addressed in this study and report. The pollution problem was discussed extensively in Section 3 and will be addressed again later in the report. Sedimentation is a natural process which is influenced by several factors. The following section presents a brief consideration of the basic principles of estuarine sedimentation which is based primarily on the report entitled, "Hydrology of Major Estuaries and Sounds of North Carolina" (see Bibliography, Section 8).

4.1.2 Principles of Estuarine Sedimentation

The mechanics of transport and deposition of sediment in an estuary are far more complex than in ordinary streams. Yet, because of the impact of sediment deposition on aquatic life and on navigation, and because large sums of money are spent in dredging and maintaining navigation channels and boat facilities, it is important to develop a clear understanding of the principles of estuarine sedimentation.

Sediment, whether moving in a free-flowing stream or in an estuary, has two components--suspended sediment and bed load. Suspended sediment is comprised of particles that are held in suspension by the upward components of turbulent currents and finer particles held in colloidal suspension. Bed load consists of material too heavy to be held in suspension but which nevertheless moves by sliding, rolling or skipping along the bed of a stream or estuary. In a free-flowing stream, however, net flow (and, therefore, sediment discharge) is always downstream and usually changes in magnitude slowly, whereas in an estuary the tide-affected flow (and, therefore, sediment discharge) generally changes rapidly in magnitude and direction. Changes in chemical quality along streams are usually small and have negligible effect on sediment concentrations, whereas quite dramatic changes in chemical quality occur within estuaries and these may profoundly influence sediment transport characteristics.

In many estuaries, a characteristic zone of high concentrations of suspended sediment and high turbidity begins near the saltwater front and, in some estuaries, continues downstream for miles. Upstream from this zone, in the freshwater portion of the estuary, concentrations are less; downstream from this zone, in the ocean, concentrations are also less. The probable explanation for this zone is that such estuaries act as sediment traps. This may be better understood by referring to the net circulation patterns on Figure 4.1 for a highly stratified estuary. Imagine suspended sediment being carried out to sea in the top layers of freshwater during ebb flow. As the time of slack water approaches where the estuary widens towards the mouth or as the freshwater spreads out over the bays and adjacent ocean, velocities decrease, thus allowing heavier sediment particles to settle. As they settle, they are entrained in water moving upstream along the channel bottom. At the upstream end of the saline water zone, flow circulates upward and downstream, and sediment particles may again be entrained upward and flow towards the sea in the upper freshwater layers. Again, the particles may settle as velocities decrease, and thus a sediment particle may be caught in a loop pattern several times.

This sediment-trap phenomenon is found to some extent in highly stratified situations, but is even more pronounced in partially-mixed estuaries where net upstream velocities near the channel bottom and net downstream velocities near the surface are much greater than in highly stratified estuaries. This pheno-

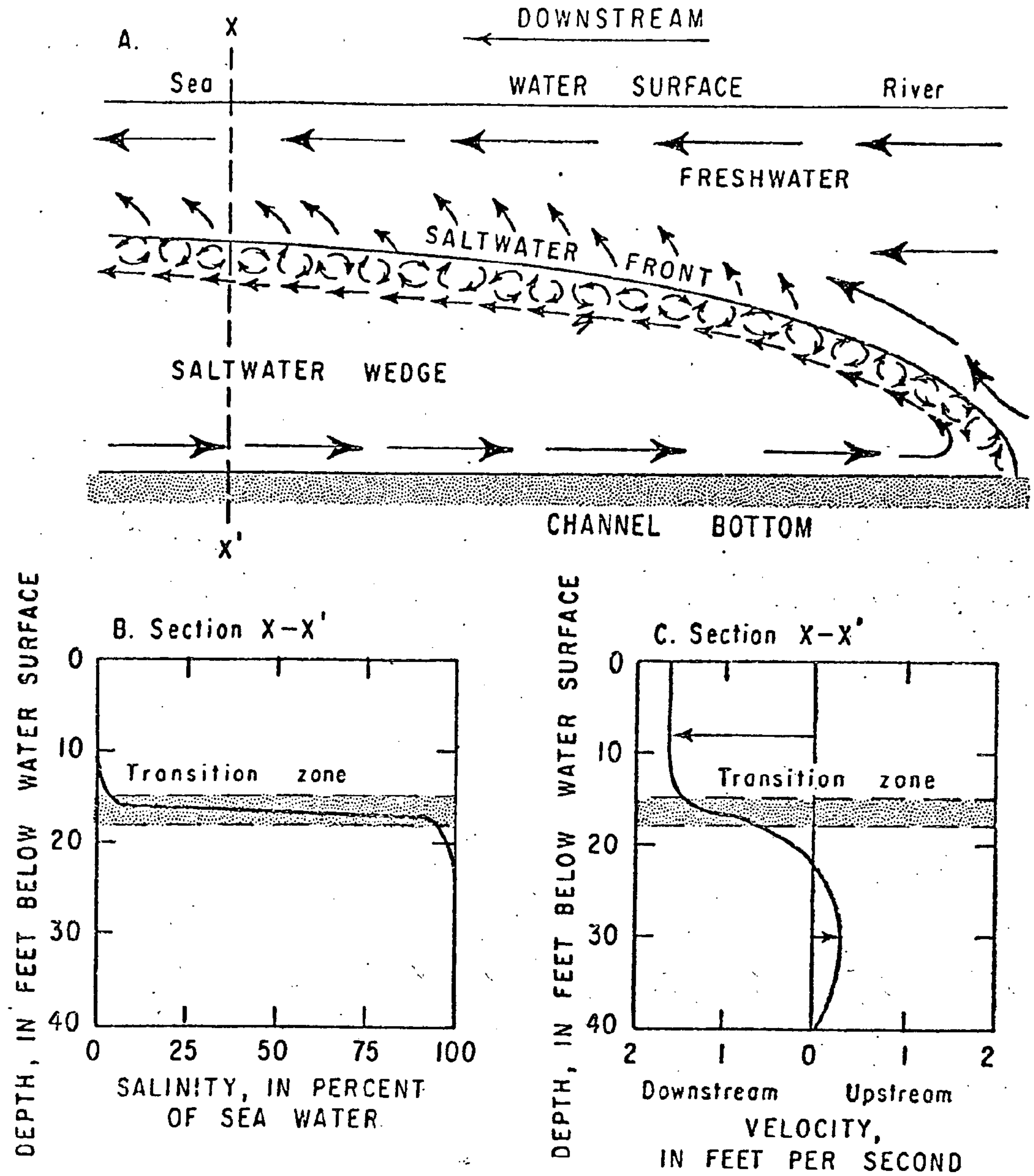


FIGURE 4.1.--A. *Net circulation patterns in a highly stratified estuary.* B. *Salinity profile through section* X - X'. C. *Net velocity profile through section* X - X'.

SOURCE:

Giese, G. L., H. B. Wilder, and G. G. Parker, Jr. July 1972. Hydrology of Major Estuaries and Sounds of North Carolina. Report of Water Resources Investigations No. 79-46, U. S. Geological Survey, Raleigh, N. C.

menon is probably not found to any significant extent in well-mixed estuaries, where there is no significant net upstream flow along the channel bottom.

The sediment trap zones in estuaries are, naturally enough, zones of high sediment deposition. Most of the deposited sediment in these zones is of clay or silt size. The particles tend to settle to the channel bottom wherever or whenever instantaneous or net velocities suddenly decrease or approach zero. The tip of a saltwater wedge is one area of rapid deposition because net velocity is zero in that vicinity. Other potential areas of deposition are where tributaries enter a slow-moving main channel, in bays, and in boat slips.

Another potential factor that may account for some sedimentation in the sediment trap zone is flocculation and subsequent deposition of clay-sized particles in the water. This process depends on the presence of electrolytes, such as sodium chloride, which neutralize the electro-negative characteristics typically associated with sediment particles. Salt water is an electrolyte, and the setting of fine-grained particles is indeed observed in the saline water zone. However an additional or alternative binding mechanism brought about by filter feeding organisms has been advanced by certain researchers based on the results of an extensive size-analysis study of particles in suspension at all depths in Chesapeake Bay and the Susquehanna River. It was reported that many composite particles were observed, particularly in the lower layer, which were agglomerates weakly bound by organic matter and mucus. These agglomerates were probably produced by filter-feeding zooplankton. Preliminary experiments have indicated that suspension-feeding zooplankton probably play a major role in the agglomeration of fine particles in the water column, and in the subsequent deposition of those particles. The large population of filter-feeding zooplankton present in the Chesapeake Bay probably filter a volume of water equivalent to that of the entire estuary at least every few weeks, and perhaps every few days.

Potential sources of silt and clay-sized sediment deposited in a sediment-trap zone are many. Studies or many United States estuaries have shown that sediment from upland discharge is inadequate in most cases to account for the shoaling rates that are observed in river channels and harbors. Other sources of shoaling material are as follows:

(1) marsh areas adjacent to the estuary with runoff draining into the tidewater,

(2) materials in larger estuaries being eroded from the shores by wave action and moving by density currents into the deeper portions,

(3) materials being displaced by dredging and propeller wash and moved by density or tidal currents,

(4) organic materials as a result of the biological cycles of estuarine plant and animal environment.

(5) industrial and human wastes discharged into the estuary,

(6) windborne sediment.

In addition to these sources, sediment resuspended from the channel bottom and later redeposited in shoaling areas may also be an important factor in high local shoaling rates in some estuaries. In some cases, the open ocean adjacent to an estuary may also be a significant source of sediment. This, and (3) above are thought to be the primary sources for shoaling occuring in the lower White Oak River estuary.

Regarding sediment deposition, and attempts to improve existing shoaling characteristics, the following points are made:

(1) sediments settling to the bottom zone in an estuary will on the average be transported upstream and not downstream,

(2) sediments will accumulate near the ends of the saltwater intrusion zone and form shoals. Shoals will also form where the net bottom velocity is

zero due to local disturbances of the regime such as by tributary channels.

(3) the intensity of shoaling will be most extreme near the end of the intrusion for stratified estuaries and will be more dispersed in the well mixed estuary.

Therefore, with regard to human interferences in existing estuary patterns, the following general rules may be derived:

(1) the major portion of sediments introduced from whatever source into an estuary during normal conditions will be retained therein, and if transportable by the existing currents will be deposited near the ends of the salinity intrusion, or at locations of zero net bottom velocity,

(2) any measure contributing to a shift of the regime towards stratification will cause increased shoaling. Such measures may be: structures to reduce the tidal flow and prism, diversion of additional freshwater into the estuary, deepening and narrowing the channel,

(3) dredging of channels should be accompanied by permanent removal of the sediments from the estuary. Dumping downstream is highly suspected and almost always useless. Agitation dredging falls into the same category. Permanent removal is desired.

Although the principals discussed in this section are useful in understanding general aspects of estuarine sedimentation, the actual movement and deposition patterns of sediment in real estuaries are usually extremely complicated in detail, and may require hydraulic model studies to adequately define. Model studies of this kind are lacking for most sounds and estuaries in North Carolina including the White Oak River.

4.1.3 Sedimentation in the White Oak River

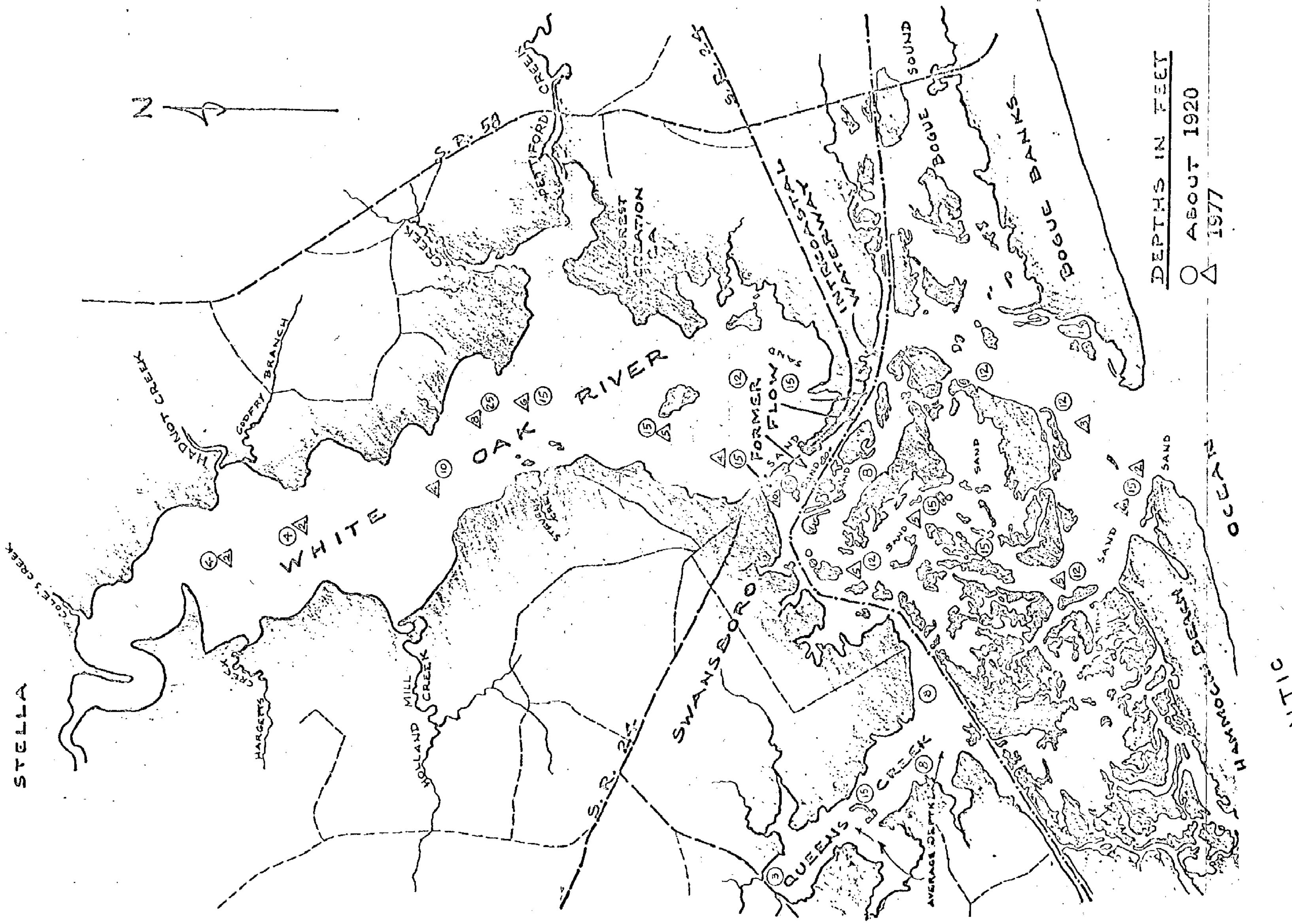
4.1.3.1 Background

In recognition of shoaling and sedimentation which was occuring in the Lower White Oak River Estuary, members of the Cape Carteret Chapter of the Issac Walton League conducted an informal study of silting problems in the river in 1977. Depth measurements were taken at several locations at low tide and plotted on a map of the lower river estuary. Also, several local fishermen, boat captains and local residents were interviewed and asked to indicate to the best of their recollection the depths in the river about the year 1920. The map was completed and subsequently published in the Tideland News of February 27, 1980. A copy of the map is reproduced in this report as Map 4.1. The map indicates a high rate of shoaling throughout the lower estuary. The publication of this map and the subsequent arousal of public concern over the matter represented one of the catalysts for the formation of the White Oak River Advisory Council.

4.1.3.2 Historical Perspectives

In an effort to obtain information on the historical depths of the White Oak River, we contacted Mr. Tucker R. Littleton, a private historian from Swansboro. Mr. Littleton kindly searched his records for information which might shed some light on the historical depths in the river and Bogue Inlet. Table 4.1 presents a listing of some fourteen ships which either were constructed at several waterfront shipyards in Swansboro and/or which used Bogue Inlet to obtain access to the Atlantic Ocean during the period from 1796 to 1897. Noting the drafts (when known) and tonnages of the vessels, it appears that "the depth of the river and inlet must have been much superior to its present condition," Mr. Littleton concludes.

Map Shows Silting Problems In River *Also in Creeks, Inlet*



Map Showing Water Depth In River, Sound & Inlet....1920 and 1977

Evidence of Shoaling Shown in Figures By Local Fishermen, *Boat* Captains, and Actual Depths Measured in 1977.

MAP 4.1

Mr. Littleton also supplied some information on the history of Swansboro as a commercial seaport. Prior to the year 1787, the inlets of Onslow County were in the customs district of the Port of Beaufort which is located in Carteret County to the east of Swansboro (the district office was actually located in New Bern, N. C.). According to the State Records of North Carolina (Volume XI), in the 1740's vessels of 6 or 7 foot draft could navigate Bogue Inlet. In March 1752, some 24 years prior to the Declaration of Independence, inspectors of exports were appointed for Bogue Inlet as one of the inspection points for the Port of Beaufort. On 26 December 1786, a Bill was passed creating the Port of Swansboro (spelled "Swannsborough" at that time), thereby establishing a customs district which included Bogue, Bear and New River Inlets. This Bill took force in March of 1787.

The importance of the port activity at Swansboro was demonstrated by the efforts of the Union forces against the Town and port during the Civil War. On 14 August 1862, a transport and seven Union steamers (the gunboat Ellis, Adelaide, Ocean Wave, Massasoit, Allison, Union, Wilson, and Pilot Boy) rendezvoused in the mouth of the White Oak River and landed Federal forces the next day, occupying Swansboro until 19 August 1862, when the steamers departed for Beaufort. In October 1862, William B. Cushing was put in command of the gunboat, Ellis. Blockade running at Swansboro was considered important enough to merit giving Lt. Cushing, as his first assignment, the job of keeping an eye on Bogue Inlet.

The White Oak River at various times in the past has been considered economically important enough to occasion several acts of the legislature to create or amend local navigation laws. For example, in 1800, "An Act to Clean and Keep Open The Navigation Of The White Oak River" was passed. In 1818, a program of canals and internal improvements was proposed with the ocean terminus to be at Swansboro. Col. Edward Pasteur of New Bern predicted that, if these improvements were in fact made, it would make Swansboro another Norfolk. Then, in 1859, the White Oak River Navigation Company was incorporated to improve navigation between Swansboro and Job Smith's Plantation. Records show that Job Smith lived near the head of the White Oak River at least 10 miles above the Maysville Bridge.

Table 4.2 presents a listing of landings along the White Oak River which indicates the importance of the river in early commerce and apparent greater depths in recent history. This list was compiled by Mr. Littleton from verbal comments and written records of the period. In addition, Mr. Littleton indicated that there are piles of discarded ballast stones near the west-northwest end of Jones Island and also along the shore at Mount Pleasant Point which indicate that there were early landings nearby, though no names for such are known today.

In 1735, by an act of the Colonial Assembly, the people of the White Oak River were ordered to pay their "quit rents" at Ross Bell's Plantation located at Mount Pleasant. At that early date, most of the settlers on the river would have used water transportation, which certainly implies a landing there. Such a landing was probably a factor in the selection of Bell's Plantation as the place for paying the annual quit rents.

In addition, at least 5 or 6 ferries were mentioned in early records as operating on the upper White Oak River. One ferry operated as early as 1731 across the river. Not long thereafter there is mention of a ferry operated from the Carteret side by Joseph Smith; another operated from Thurrell's Bluff on the Onslow County side by Francis Thurrell; and still further upstream there was a ferry operated by Francis Brice. Brice's Ferry appears on a 1733 map of N. C. by Moseley. Still another ferry operated at Smith's Mills in the 1800's. Each

TABLE 4.1

Listing of Vessels Using the Port of Swansboro and Bogue Inlet[1]

Item No.	Year	Vessel Type/Name	Draft (Ft.)	Documented Tonnage	Comments
1.	1857	Schooner D. W.Sanders	8	159	Docked at Swansboro
2.	1897	Barge Swansboro	--	188	Built at Swansboro
3.	1841	Schooner Onslow	--	130	" " "
4.	1833	Schooner Caleb Nichols	10[2]	163	" " "
5.	1834	Schooner Zenith	--	103	" " "
6.	1832	Brig Solomon Status	--	316	" " "
7.	1828	Brig Onslow	--	150	" " "
8.	1825	Schooner Turpentine	--	118	" " "
9.	1827	Brig Burdette	--	245	" " "
10.	1810	Brig Eliza Lord	--	159	" " "
11.	1799	Brig Hunter	--	109	" " "
12.	1797	Schooner Frederick	--	113	" " "
13.	1796	Brig Lewis	--	121	" " "
14.	1814	Ship (unnamed) owned by firm of Carroll and Dudley of Swansboro, North Carolina	--	"about 600"	" " "

1./ Source: Tucker R. Littleton, Private Historian, Swansboro, N. C. (compiled from newspaper accounts and nautical records of the period).

2./ When loaded.

TABLE 4.2

LIST OF LANDINGS ALONG THE WHITE OAK RIVER ABOVE THE SWANSBORO BRIDGE[1.]

ITEM NO.	NAME OF LANDING	LOCATION	COMMENTS
A. Onslow County (Proceeding Upstream)			
1.	New Harmony	About 1/2 way between Swansboro and Mount Pleasant Point on New Harmony Creek	New Harmony Creek is also known in recent years as Canady's Creek or Corbett's Creek
2.	McGee's	Southwest corner of Jones Island	Jones Island is also called Bell's Island
3.	Freeman's	On White Oak River at Swift's Marshes	Also known as Crumpler's Landing
4.	Machine Tract	On river just above Stephen's Creek	- - - - - - - - - - -
5.	Cahoon Point	On river at Cahoon Point	- - - - - - - - - - -
6.	Red Hill	On river just below the Scott Place	See 7, 8
7,8.	Scott Place	Two landings; one on river front and one just inside Holland's Mill Creek	- - - - - - - - - - -
9.	Will Odum's	On port side going up Holland's Mill Creek	- - - - - - - - - - -
10, 11.	Curt Holland's	Two landings on starboard side of Holland's Mill Creek above George Odum's Landing	See 12

TABLE 4.2
Landings, Continued

ITEM NO.	NAME OF LANDING	LOCATION	COMMENTS
12.	George Odum's	Just inside Holland's Mill Creek on starboard side, going upstream	- - - - - - - - - -
13.	Elm	On river just above Hargett's Creek	Shown on USGS map, Hubert Quad
14.	Freeman's	At Freeman's Creek	Note: Not to be confused with 2 other landings by same name
15.	Freeman's	Inside Webb's Creek	- - - - - - - - - -
16.	Sloan's	On Webb's Creek	- - - - - - - - - -
17.	Koonce's	On Koonce's Bay opposite Ned's Creek	- - - - - - - - - -
18.	Brick Kiln	Just below Stella Bridge	- - - - - - - - - -
19.	Mattocks's	Just above Stella Bridge	- - - - - - - - - -
20.	Dorton's	Above Stella Bridge	Shown on 1921 soil survey map of Onslow County
21.	Bullock's Landing	Up Grant's Creek	An important commercial landing
22.	Bunga	Up Grant's Creek	- - - - - - - - - -
23.	Aman's	About 0.5 mile upstream of mouth of Grant's Creek on Riverfront	- - - - - - - - - -

TABLE 4.2
Landings, Continued

ITEM NO.	NAME OF LANDING	LOCATION	COMMENTS
B. Carteret County (Proceeding Upstream)			
24.	Boathouse Creek	Up Boathouse Creek	- - - - - - - - - - -
25.	Salt Works	On Salt Works Point across channel from Jones Island	- - - - - - - - - - -
26.	Charlie Dudley's	Up Pettiford Creek on starboard side, going upstream	Called Pettiver's Creek on old maps
27.	Piner's	Just below bridge on Pettiford Creek on starboard side	- - - - - - - - - - -
28.	Meadows's	Just inside mouth of Starkey's Creek at confluence with Pettiford Creek	- - - - - - - - - - -
29.	Unknown	Near head of navigation of Starkey's Creek	- - - - - - - - - - -
30.	Norris's	On Morton's Point at Pettiford Creek	- - - - - - - - - - -
31.	Windy Point	Windy Point at mouth of Pettiford Creek	- - - - - - - - - - -
32.	Truckner's	Near where Pettiford Creek Bay joins the river	- - - - - - - - - - -
33.	Wiggins's	On river at Wiggen's Shore	- - - - - - - - - - -

TABLE 4.2
Landings, Continued

ITEM NO.	NAME OF LANDING	LOCATION	COMMENTS
34.	Morse's	Near Bernard Morse property	Called Moss's Landing locally
35.	Watson's	On Hadnot's Creek	- - - - - - - - - -
36.	Ned's	Up Ned's Creek	- - - - - - - - - -
37.	Wetherington's	On property formerly owned by Charles Wetherlington	- - - - - - - - - -
38.	Barker's	Short distance below Stella	- - - - - - - - - -
39.	Unknown	Immediately below Stella Bridge	This landing was used by a lumber-mill during Stella's "Lumber Boom", in the late 1800's
40.	Ervin's	Short distance above Stella Bridge	- - - - - - - - - -
41.	Unknown	Located where first high land touches Hunter's Creek near its mouth, on starboard side going upstream	- - - - - - - - - -
42.	Tantrough	Located up Hunter's Creek half way between mouth of creek and NC 58 bridge	- - - - - - - - - -

TABLE 4.2
Landings, Continued

ITEM NO.	NAME OF LANDING	LOCATION	COMMENTS
C. Jones County (Proceeding Upstream)			
43.	Long Point	Above Hunter's Creek at Long Point	At least early 19th century landing
44.	Haywood's	Above Long Point	A colonial landing site
45.	Holston's Creek	Just inside mouth of creek on port side, going upstream	An early 18th century landing
46.	Gillett's	Near Holston's Creek landing on the riverfront	- - - - - - - - - -
47.	Tom Collins's	On the White Oak River just above Gravelly Branch	On adjacent high ground, there are remains of an 18th century homesite

1./ Listing compiled by Mr. Tucker Littleton, Historian, Swansboro, N.C. from oral and documented sources.

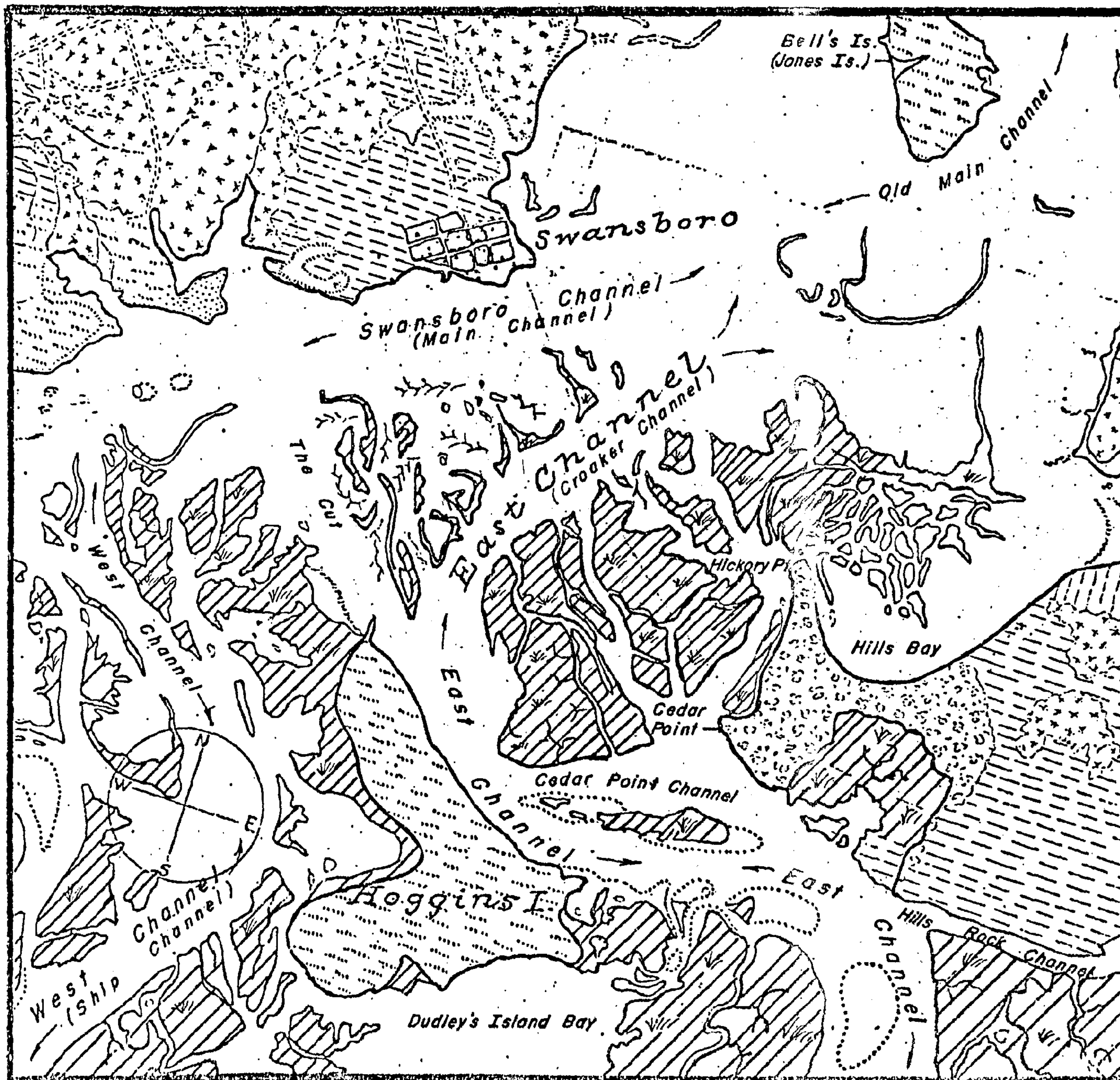
of the foregoing ferries should add two landings to the list of White Oak River landing sites. The ferry landings may have received other use, since the court directed in the case of Francis Thurrell that his ferry landing "be deemed a public landing" for the use of the public.

Mr. Littleton also indicated that oral informants have indicated that Jones's Island (formerly known as Bell's Island) which is located north of Route 24 Bridge in mid river was at one time (over 100 years ago) connected to the mainland by a low-lying land bridge. Access was gained at low tide from Mount Pleasant Point on the Onslow County side of the river. Remnants of farming activities on the island testify to the former use of this land. The main river channel also skirted the southeastern side of the island when Onslow County was established (see Map 4.2 following).

In an effort to more clearly define the more recent series of events which have led to the existing conditions in the lower estuary, a series of maps of the lower White Oak River estuary were obtained from the Wilmington District Office of the U.S. Army Corps of Engineers. These maps accurately reflect the changes that have taken place in the area over the period of 1873 to the present.

An 1873 map, the first in the series, (source unknown) shows very little development in the area except for the Town of Swansboro and scattered cultivated fields and homes on the western and eastern mainland shorelines. There were no permanent developments on Bogue Banks or Bear Banks (Hammocks Beach). The area of the river between Swansboro and Cedar Point consisted of two deep channels, called the "Swansboro Channel" and "East Channel", plus a narrow shallow channel (unnamed) near Cedar Point (see Map 4.2).

It is assumed from this map that the principal flow of the river was through the deeper channels, with sheet flows occuring over the easternmost



MAP 4.2

WHITE OAK RIVER IN THE VICINITY OF SWANSBORO, N. C., 1873.

SOURCE OF MAP: U. S. ARMY CORPS OF ENGINEERS, WILMINGTON DISTRICT.

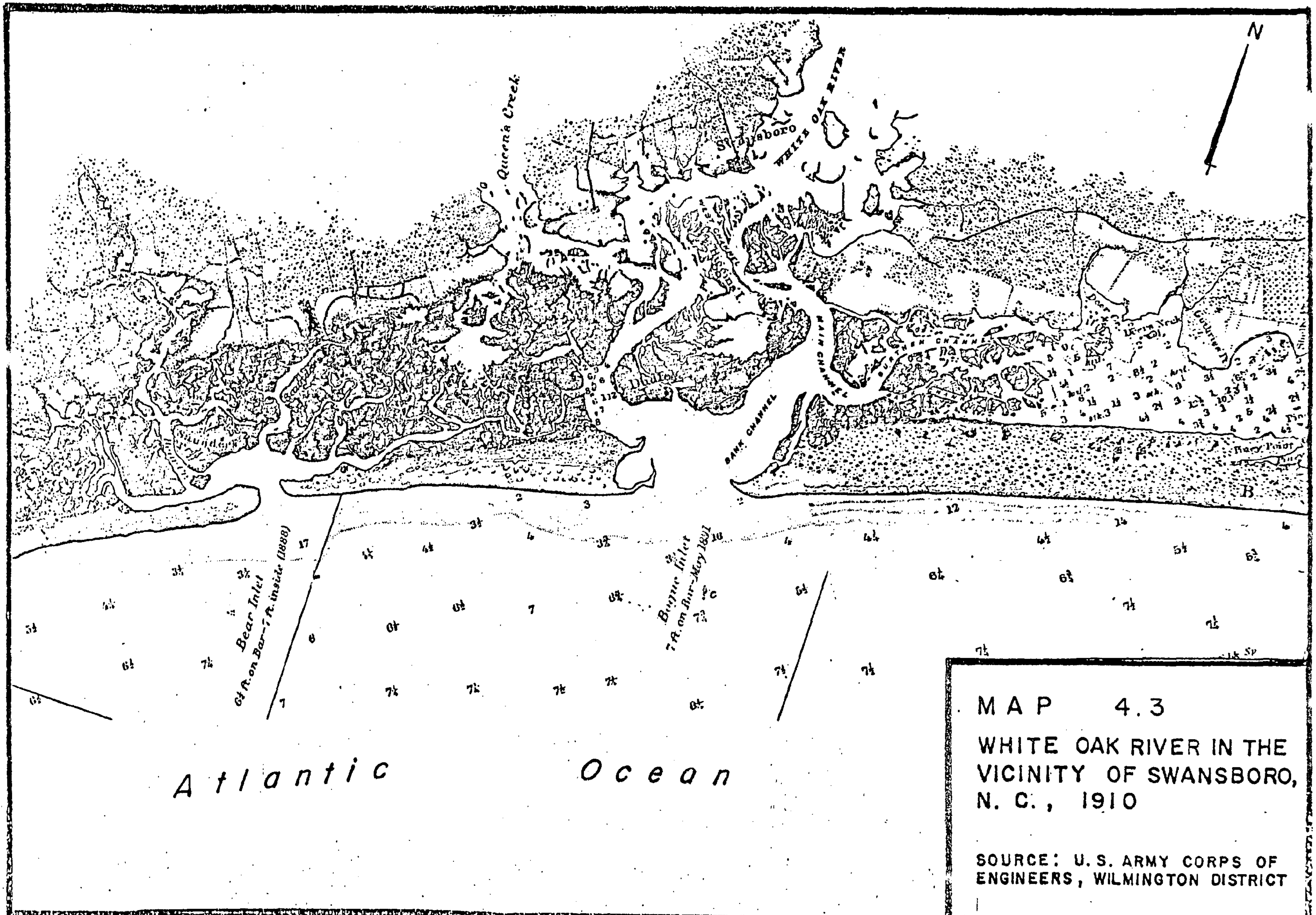
SOURCE OF NAMES: Mr. TUCKER R. LITTLETON, HISTORIAN, SWANSBORO, N. C.

shoals and marshes during freshets, the higher spring/fall tides or during storm tides.

The second map from the year 1910 (source unknown) shows little apparent change from 1873 (see Map 4.3). However, this map shows water depths in the West Channel of Bogue Inlet (between Dudley's Island and Bear Banks). Depths of up to 12 feet are noted in this area, which indicates that this channel was navigable at this period of history. Some depths in Bogue Sound between West Bogue Banks and what is now Cape Carteret are also shown on this map.

The third map in the series dates from the year 1928 (see Map 4.4). This map records a survey for the then proposed Atlantic Intracoastal Waterway. Of considerable interest are the water depths shown on this map for the East Channel and the unnamed shallow channel nearest Cedar Point. The former channel had a maximum depth of 11.6 feet and the latter a maximum of 2.7 feet. This map also confirms the apparent navigability of the West Channel, the westernmost channel from Bogue Inlet to Swansboro, with depths of up to 18 feet being recorded by the survey team. In contrast, depths in the easternmost channel of Bogue Inlet, incorrectly called the "West Channel" on this map, show a maximum of about 10.9 feet. However, this same channel at Swansboro only showed depths of 1.8 to 3.1 feet which are much more shallow than present depths. Thus, it is tentatively concluded that at this time most of the flow of the White Oak River was through the East Channel near the midpoint of the river between Swansboro and Cedar Point.

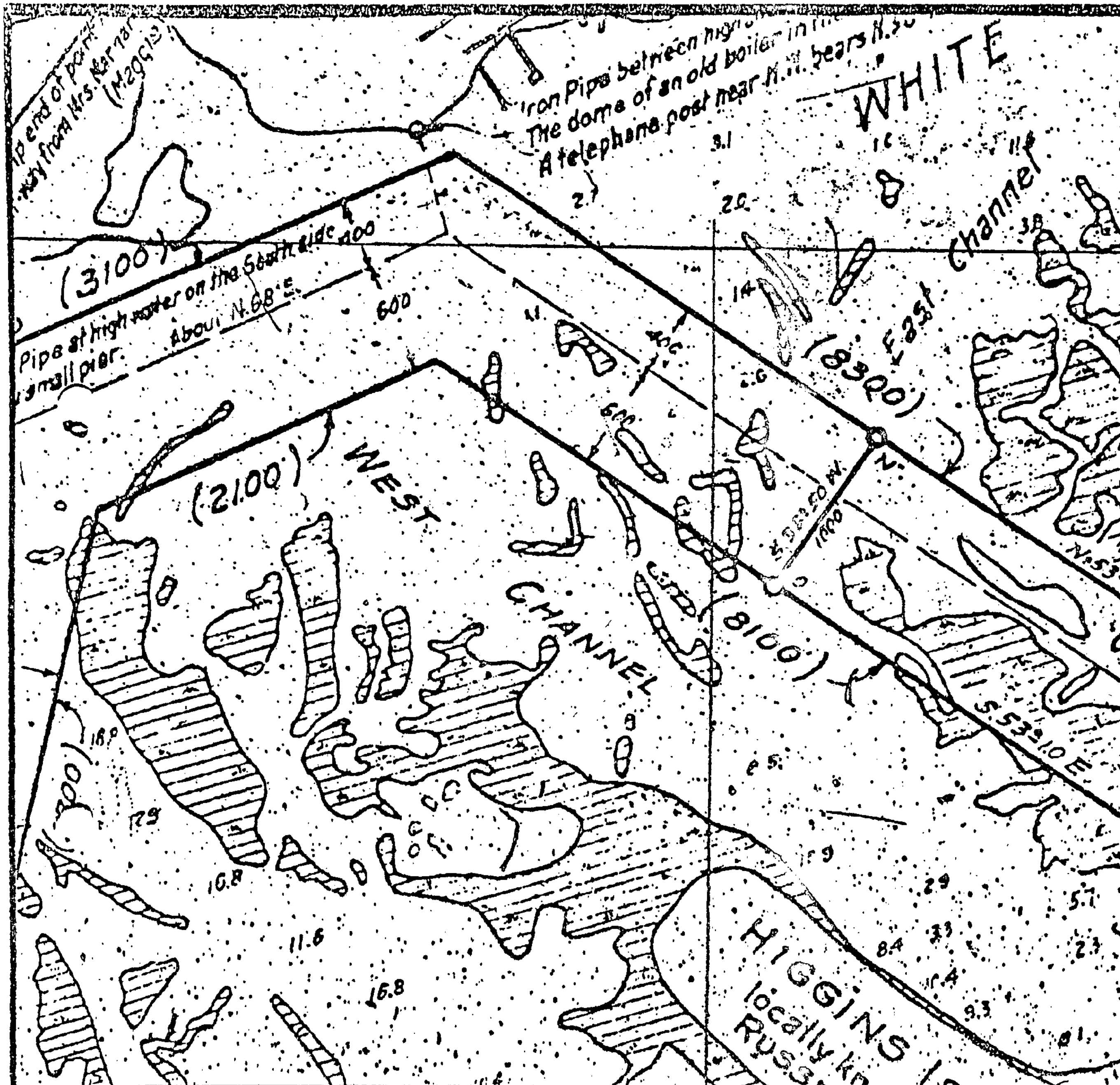
The next map is a 1932 Corps of Engineers map of the right-of-way of the AIWW which was apparently produced immediately after the construction of the waterway canal (see Map 4.5). This map shows the original uncontained spoil areas which were developed during construction of the waterway. The easternmost unnamed channel of the White Oak River near Cedar Point was closed off at this



MAP 4.3

WHITE OAK RIVER IN THE VICINITY OF SWANSBORO, N. C., 1910

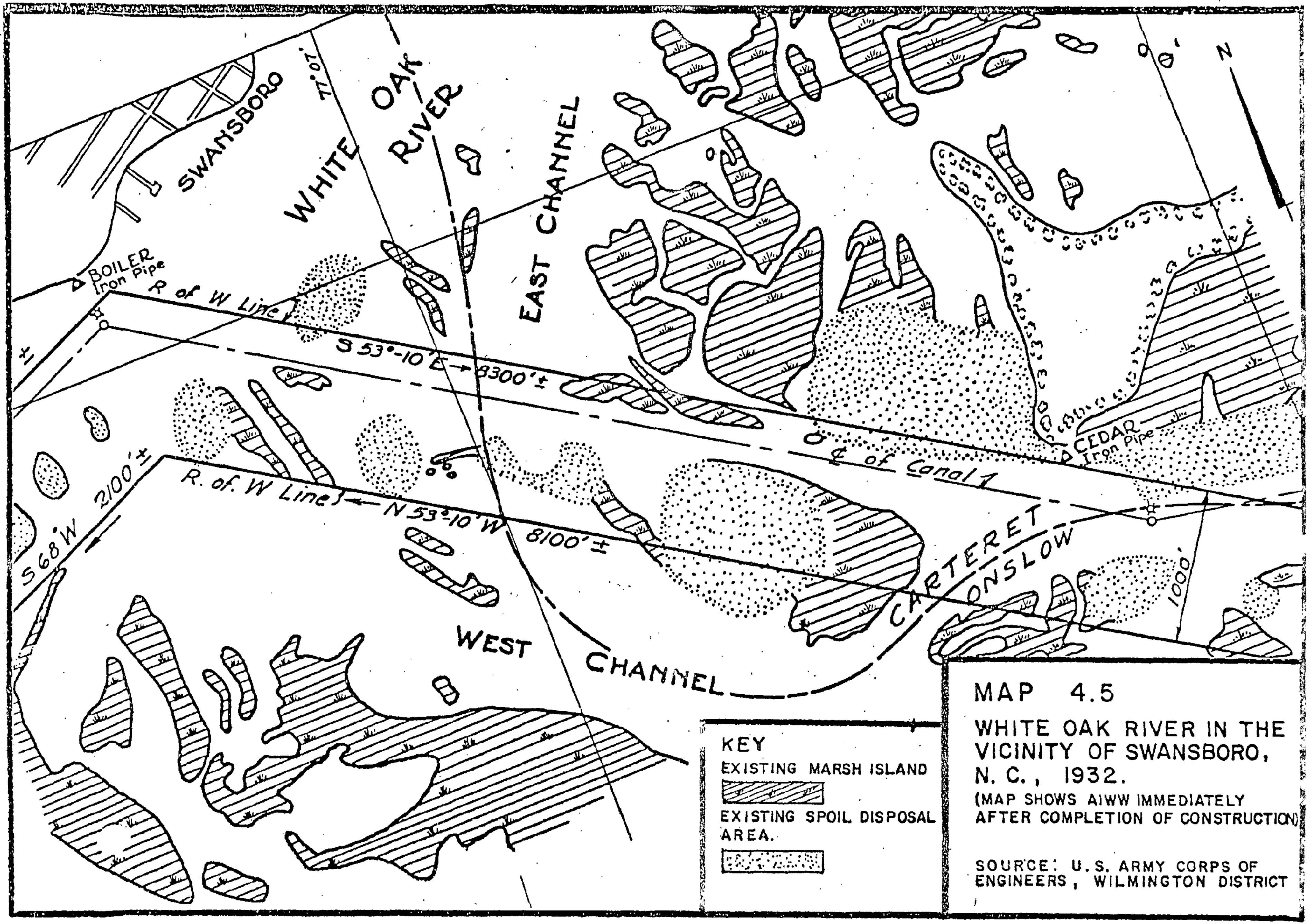
SOURCE: U. S. ARMY CORPS OF ENGINEERS, WILMINGTON DISTRICT



MAP 4.4

WHITE OAK RIVER IN THE VICINITY OF SWANSBORO, N.C., 1928. (MAP SHOWS THE PRECONSTRUCTION SURVEY OF THE A.I.W.W.)

SOURCE: U.S. ARMY CORPS OF ENGINEERS, WILMINGTON DISTRICT



MAP 4.5

WHITE OAK RIVER IN THE VICINITY OF SWANSBORO, N. C., 1932.

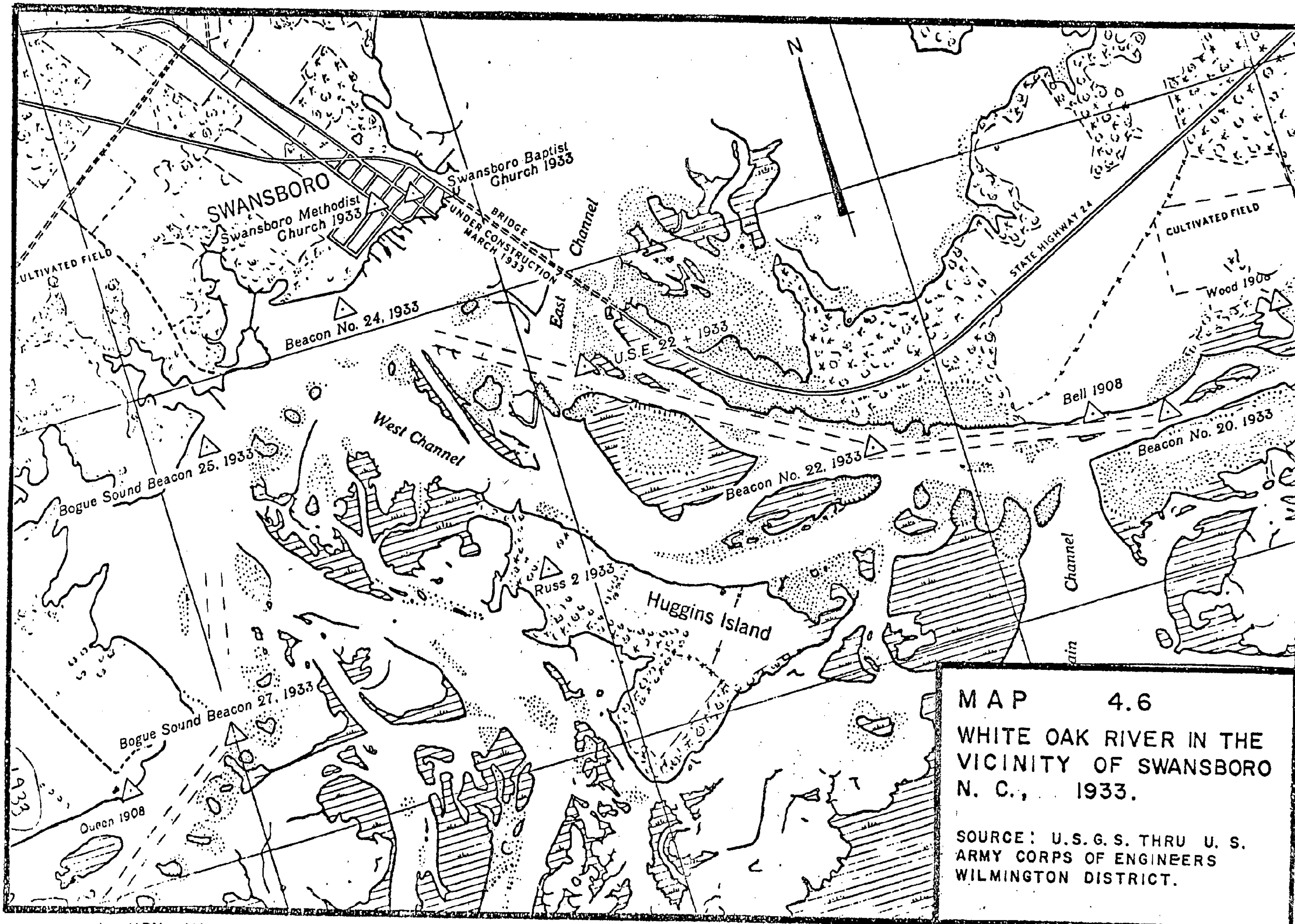
(MAP SHOWS AIWW IMMEDIATELY AFTER COMPLETION OF CONSTRUCTION)

SOURCE: U.S. ARMY CORPS OF ENGINEERS, WILMINGTON DISTRICT point by uncontained spoil dredged from the canal. Also, the lower portion of the East Channel was closed off by spoil. Several other spoil islands were created along the right-of-way corridor in the lower estuary. Their locations are also shown on this map. The placement of these spoil islands and the construction of the AIWW itself certainly had a significant impact on circulation patterns and riverine flows in the area, and ultimately affected the shoaling process evident today.

The next map in the series dates from 1933 (see Map 4.6). It shows the AIWW and the Route 24 bridge over the White Oak River under construction as of March, 1933. No water depths are indicated on this map. However, the map does show that State Highway 24 was placed on a hydraulic fill causeway at Cedar Point which closed off all water flow east of the East Channel of the river. This construction work certainly also had a profound effect on the circulation, water flow patterns and shoaling patterns in the lower estuary.

The last map of the series obtained from the Corps of Engineers is a portion of a 1949 USGS map of the Swansboro quadrangle (see Map 4.7). The map does not include any water depths, but does reveal that the causeway area at Cedar Point had by that year been developed for urban uses. The fixed wood bridge is also shown on the map. No development was shown on the hydraulic fill section in mid river between the two spans across the channels. This development was to take place after this date, perhaps following completion of the NCDOT's bridge replacement project of the early 1950's.

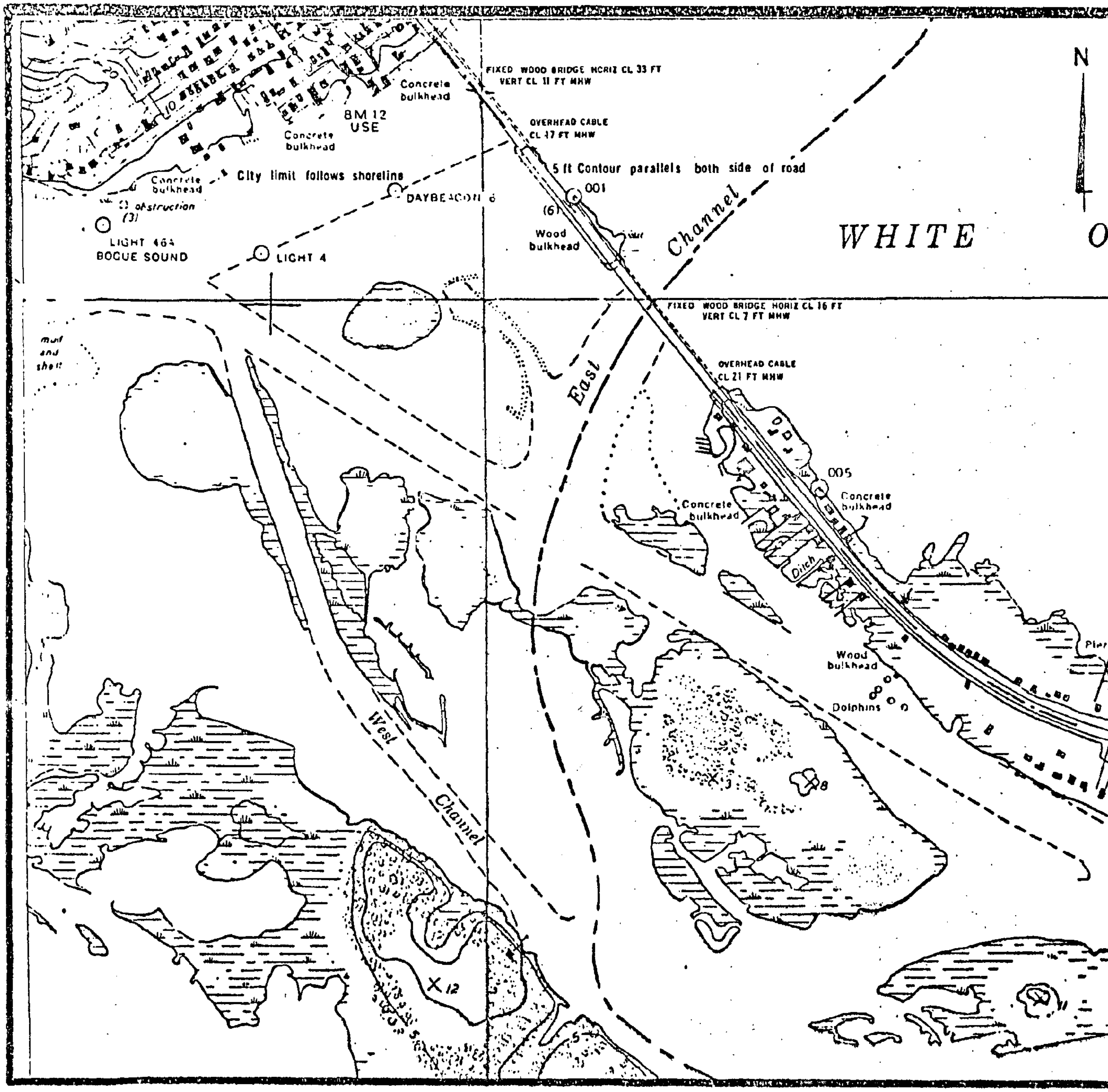
Existing conditions in the lower river area are shown in a series of aerial photos dated March 12, 1979, which were flown by Precision Photo Laboratories, Inc., Dayton, Ohio for the Wilmington District Corps of Engineers. Photo Plates 4.1 to 4.6 were taken on the ebb tide on the above specified date.



MAP 4.6

WHITE OAK RIVER IN THE VICINITY OF SWANSBORO N. C., 1933.

SOURCE: U.S.G.S. THRU U. S. ARMY CORPS OF ENGINEERS WILMINGTON DISTRICT.



MAP 4.7

WHITE OAK RIVER IN THE VICINITY OF SWANSBORO N. C. 1949

SOURCE: U. S. G. S. THRU U. S. ARMY CORPS OF ENGINEERS, WILMINGTON, N. C. DISTRICT.

HENRY VON OESEN & ASSOCIATES – CONSULTING ENGINEERS & PLANNERS – WILMINGTON, N. C.

Plate 4.1 shows the bridge-causeway complex area and a portion of the upper river up to an area opposite Mount Pleasant Point on the Onslow County side of the river. This plate clearly reveals a series of fan-like shoals or bars which extend on either side of the Swansboro and East Channels of the river north of the bridge-causeway complex. These shoals extend north to Jones Island and beyond. The presumption is that these shoals were created in recent times by the redistribution of sediments from the unconsolidated spoil areas which were created during the construction of the AIWW, and by alteration in the flow patterns and channel hydraulics resulting from both the AIWW dredging and the causeway/bridge construction.

Plate 4.2 shows the AIWW and portions of the lower river and the eastern channel of Bogue Inlet where they intersect with the AIWW. Remnants of the old East Channel in the vicinity of Huggins Island are clearly visible in this photo. The spoil islands created during the construction of the AIWW are also visible in the photo as is a recurring shoal at the intersection of the East Channel of Bogue Inlet and the AIWW.

Plate 4.3 shows a portion of the AIWW and the northern section of the eastern channel of Bogue Inlet. Extensive shoals are visible in the upper inlet area.

Plate 4.4 shows the mouth of Bogue Inlet including West Bogue Banks, Hammocks Beach (Bear Banks) and the gorge of the inlet.

Plate 4.5 also shows the mouth of the inlet, but also a portion of the ebb tide discharge fan.

Plate 4.6 concludes the series with a view of the entire stained discharge plume or fan in contrast to the clearer ocean waters.

Taken in perspective, it is clear that there are several factors which have influenced the shoaling in the lower river estuary. Section 4.1.2 shows that

PHOTO PLATE 4.1

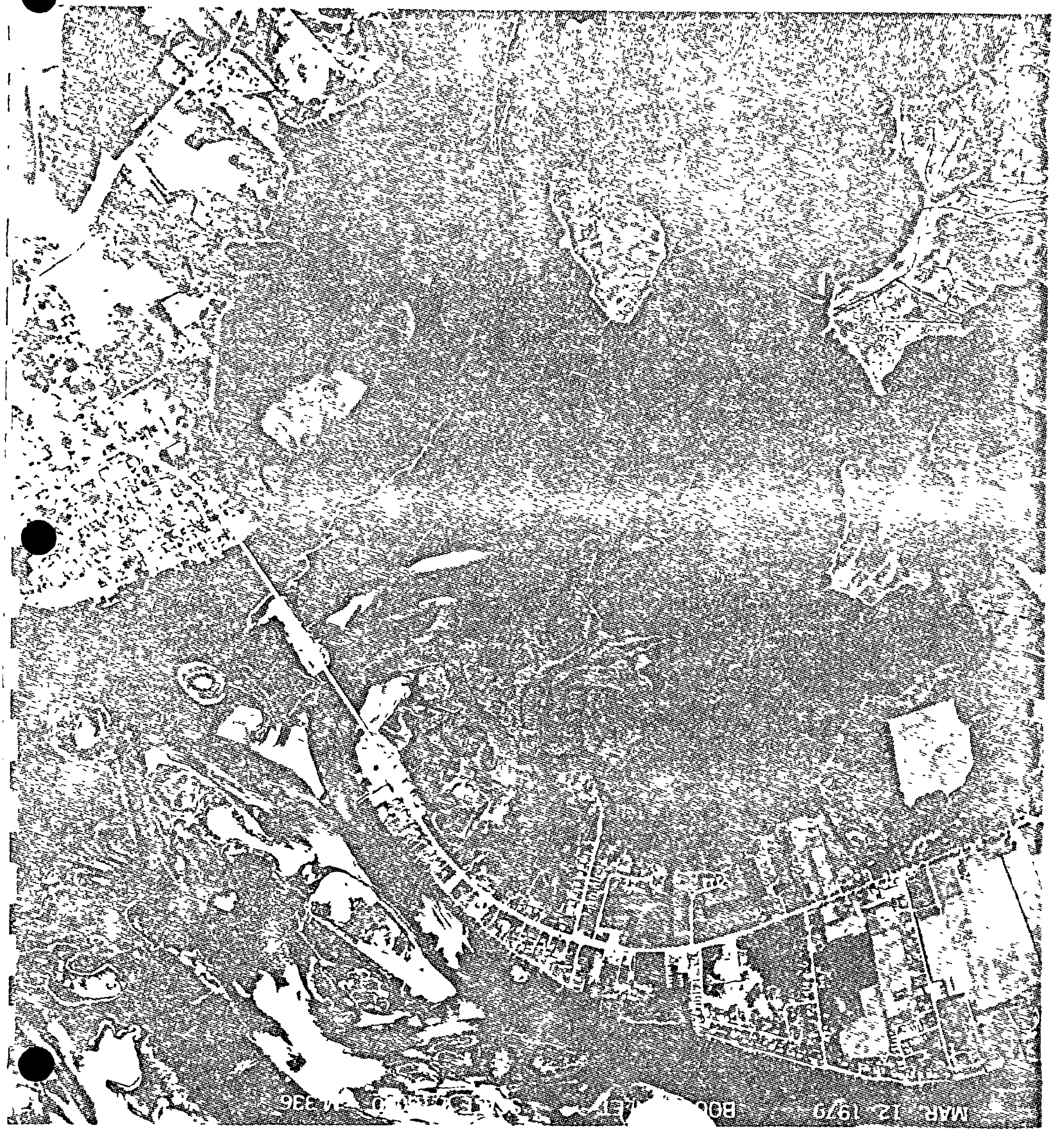


PHOTO PLATE 4.2

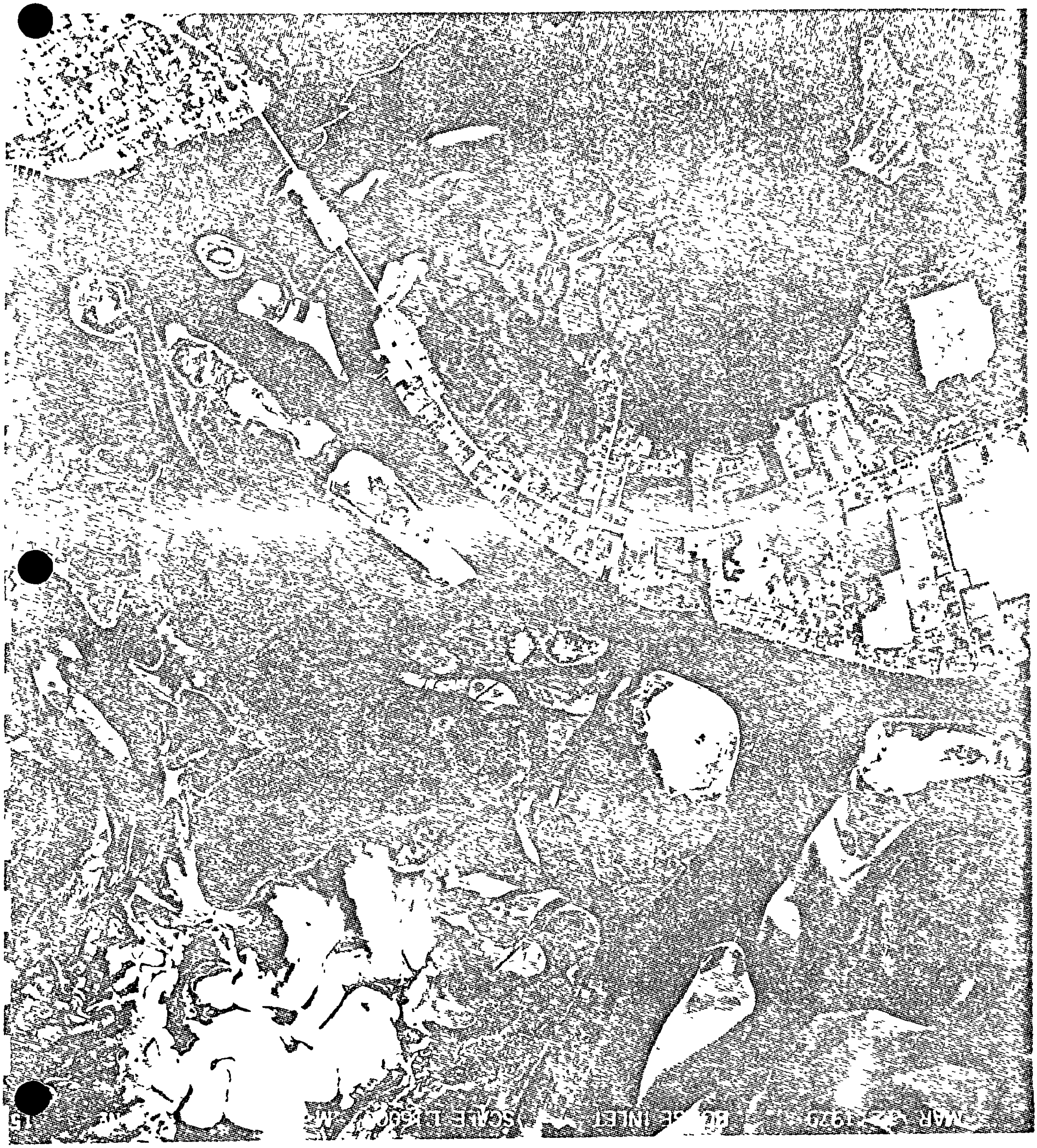


PHOTO PLATE 4.3

PHOTO PLATE 4.4

PHOTO PLATE 4.5

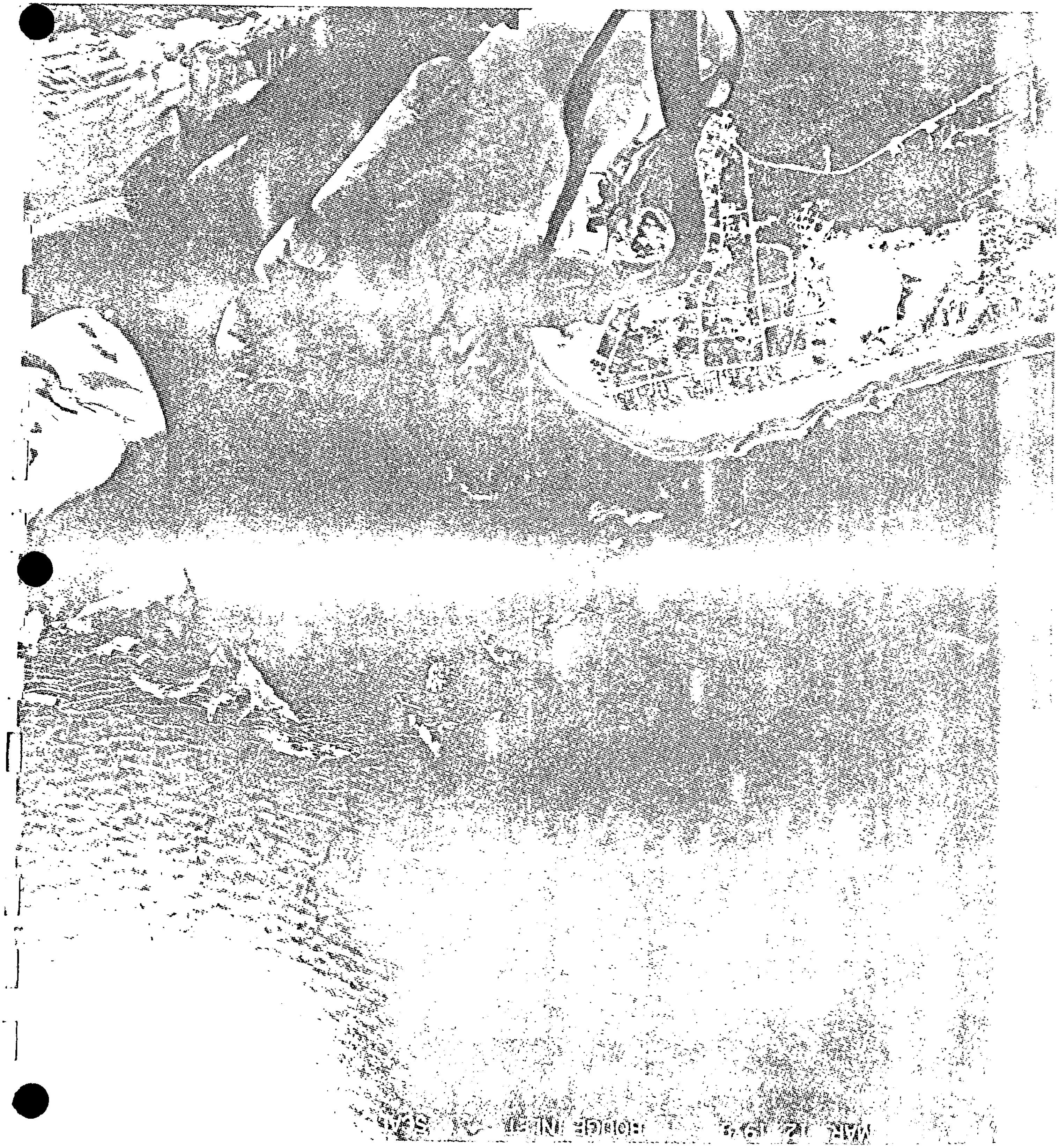
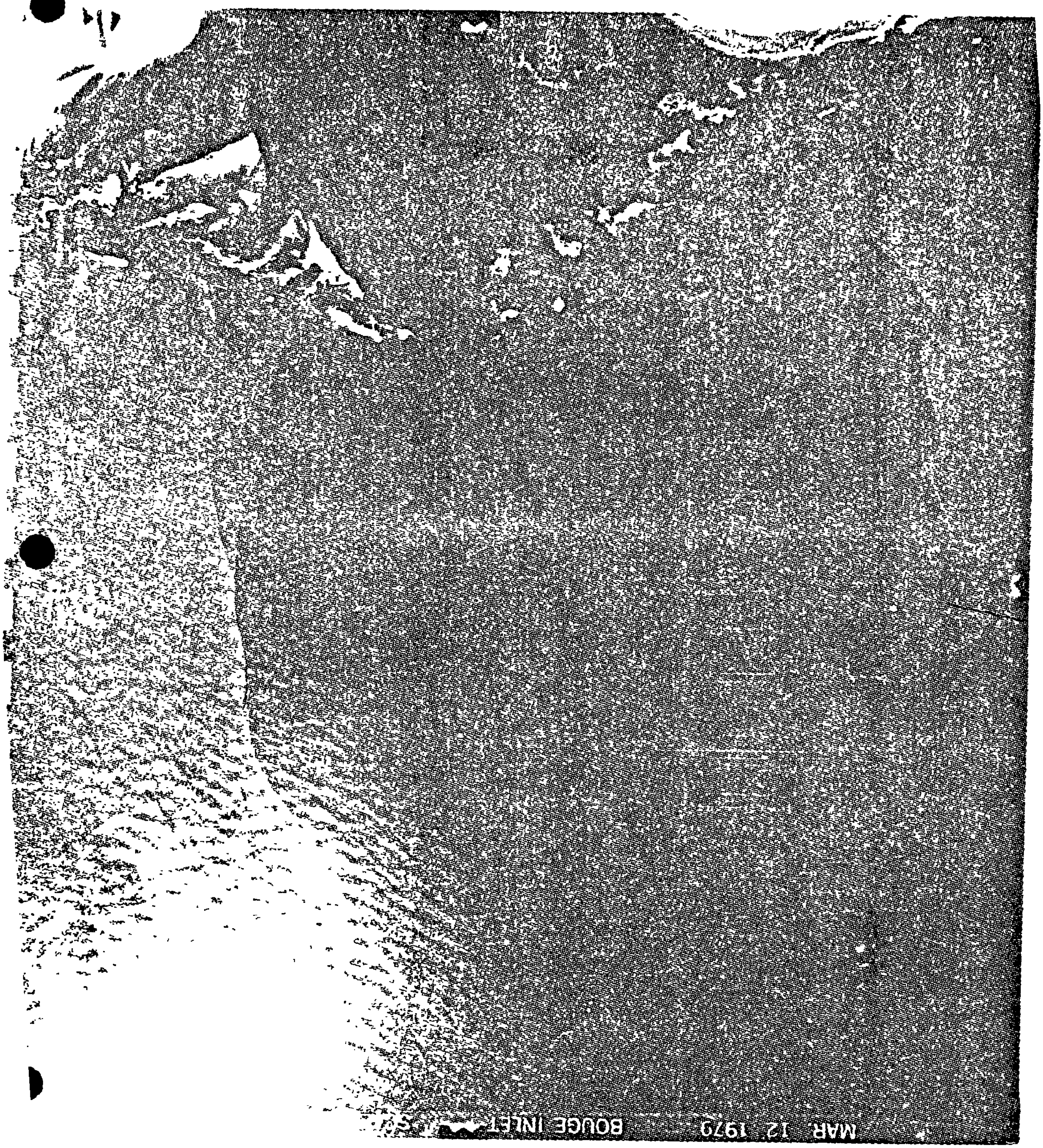


PHOTO PLATE 4.6

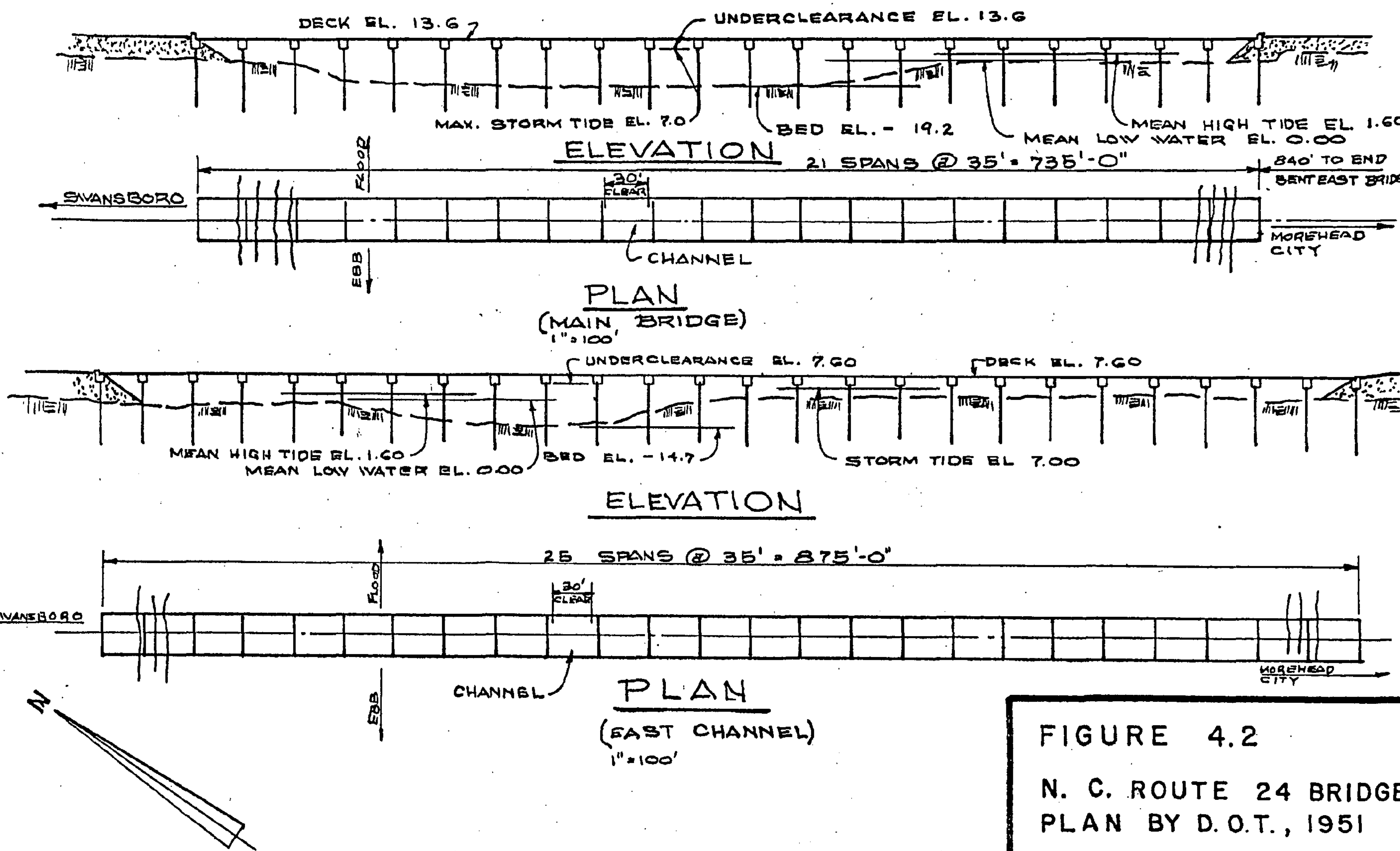


sedimentation is a natural process which is expected to occur in any estuary including the White Oak River without the intervention of man. In Section 4.1.3, we have shown that man's actions have also had an influence, especially during the last century. In the sections which follow, we discuss the factors influencing sedimentation in greater detail including the construction of the Swansboro-Cape Carteret Bridge-Causeway Complex, the construction of the Atlantic Intracoastal Waterway, and the roles of Bogue Inlet, storm surge and upstream sources of sediment in the overall regime of sediment dynamics.

4.1.3.3 Swansboro-Cape Carteret Bridge-Causeway Complex

Contacts made with the Hydrographic Division of the N. C. Department of Transportation, Raleigh, N. C. revealed that plans for the original Swansboro to Cedar Point Bridge and Causeway Complex were drawn up in September, 1932. Based on the best available information, actual construction of the roadway complex took place beginning in 1933. The 1932/33 project (NCDOT Project No. 3690) consisted of a timber pile and structure bridge over the Swansboro channel of the White Oak River at Swansboro, a roadway and hydraulic fill section behind a timber bulkhead in mid river between the West and East Channels, a second timber pile supported bridge structure over the East Channel and a roadway on hydraulic fill on the Cedar Point side of the river. The total length of the project was 1.413 miles consisting of 1.115 miles of roadway and 0.298 miles of bridge structures. As a result of this project with the placement of the hydraulic fill exclusive of the bridge piles, the overall width of the river was reduced from about 2,200 feet to 850 feet. The remaining 850 feet of open water was divided into nearly equal segments, the West (Swansboro) Channel area (400 feet wide) and the East Channel area (450 feet wide) (see Figure 4.2).

Based on interviews and discussions with several knowledgeable individuals, it has been suggested that the road-fill construction method was employed at the



NOTE: DATA OBTAINED FROM N.C. HIGHWAY PUBLIC WORKS SURVEY PARTY 10/30/51.

FIGURE 4.2

N. C. ROUTE 24 BRIDGE PLAN BY D.O.T., 1951 request of local interests who felt that this newly created land would provide a "developable asset". However, it is felt that economic considerations were the primary factor influencing the State decision to construct the crossing using the road- fill and bridge structure combination rather than an elevated span on piles.

In the fall of 1951, the NCDOT drew up plans for the replacement of the original wooden bridges and roadway with more substantial concrete bridges and new pavement. The new roadway and bridges were located about 32 feet north and upstream of the original system. Following construction, which we assume was conducted in 1951/52, the wood bridges and piles were removed by the Contractor. This replacement project did not substantially alter the width of the river with the two aforementioned channels being retained. The water depths in the West (Swansboro) Channel in 1951 are shown in Figure 4.3.

Based on plans furnished by NCDOT and limited field surveys conducted in January 1981, we have plotted the river depths in the vicinity of the bridges and causeway for the years 1932, 1951 and 1981 (see Figure 4.4). These profile plots show the changes to date which have occured since the bridge/causeway complex was constructed.

Figure 4.4 indicates that the Western or Swansboro Channel deepened from 1932 to 1951 with little change evident from 1951 to present. On the other hand, the profile plots of the East Channel reflect a condition of progressive shoaling (decrease in depth) from 1932 to the present. These profiles indicate that since 1932, the Swansboro Channel has apparently assumed the role as the main channel of the river while prior to 1932 the East Channel was the deeper of the two channels. These depth changes were in direct response to the construction of the AIWW and the highway bridges beginning in 1932.

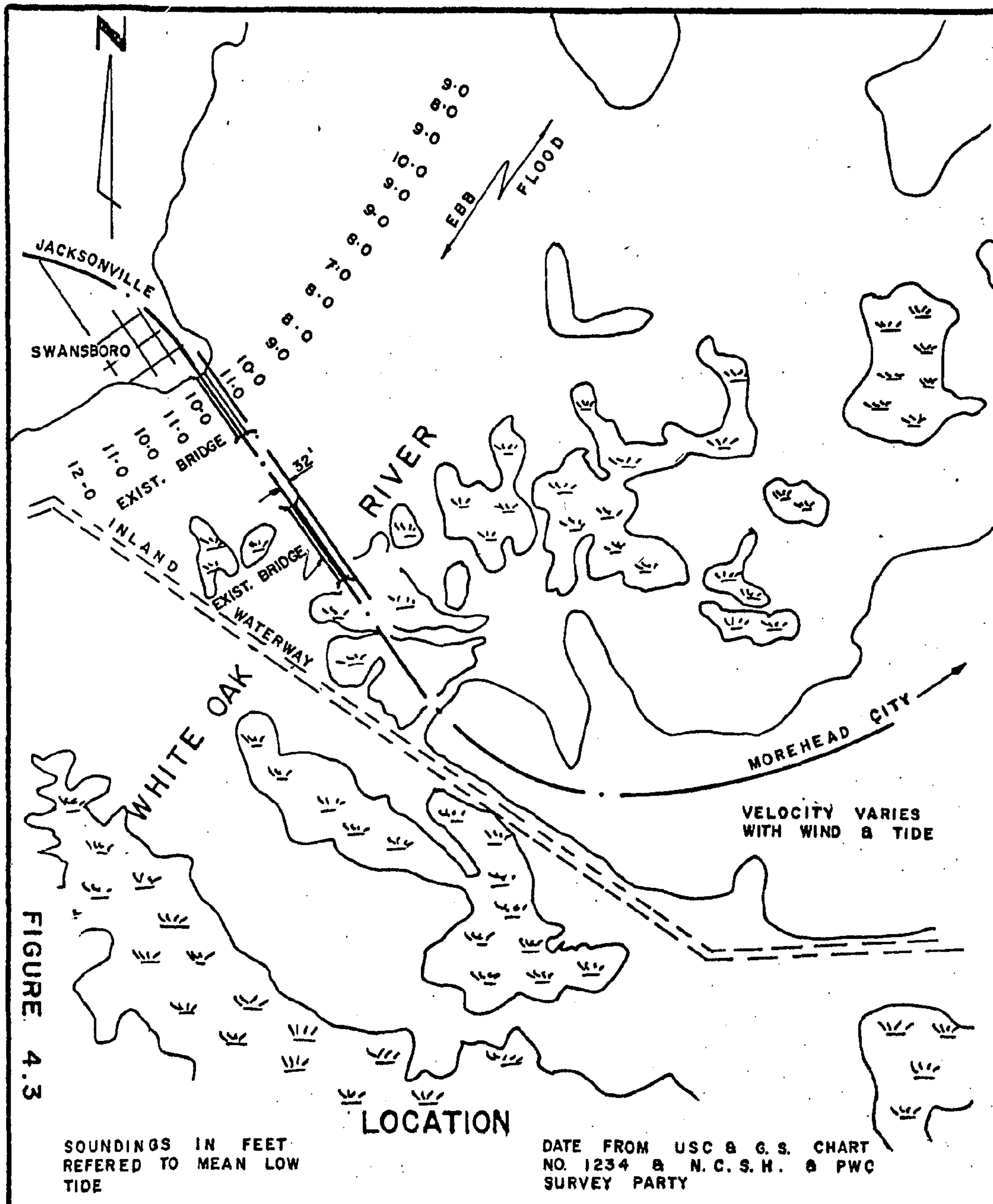
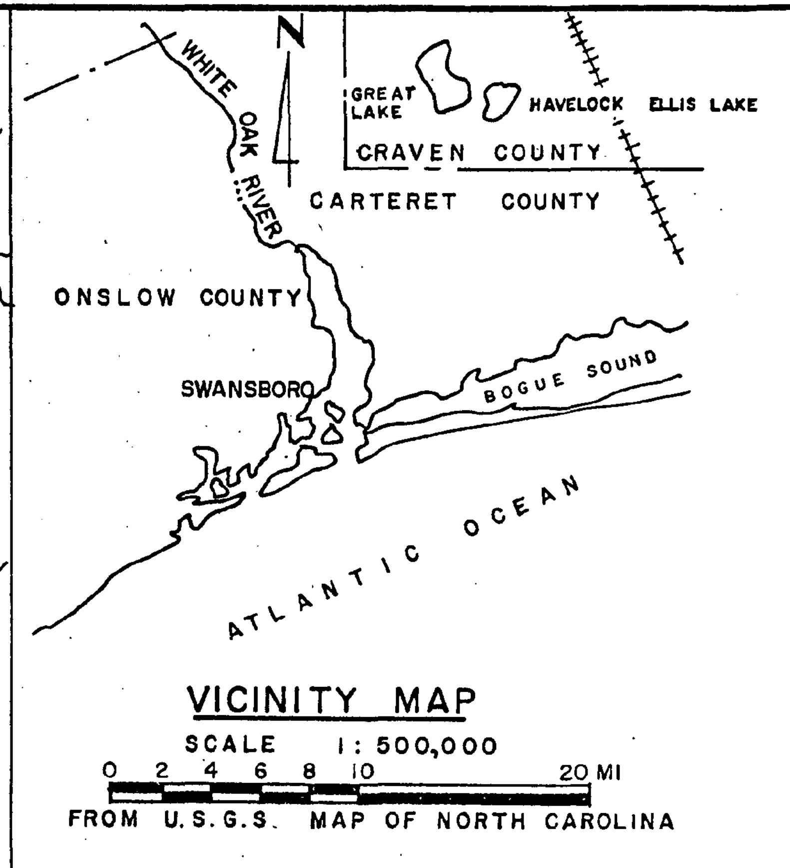


FIGURE 4.3



PROPOSED HIGHWAY BRIDGES
AND CAUSEWAY
ACROSS WHITE OAK RIVER
ONSLOW AND CARTERET COUNTIES
N. C. STATE HWY. & PUBLIC WORKS COMM.
IN 2 SHEETS - SHEET NO. 1

SCALE 1 : 20,000
0 500 1000 2000 3000 4000 Ft.

CHECKED BY : R.F.N. OCT. 30, 51

MAP TRACED FROM DWG. BY N.C. STATE HWY & PUBLIC WORKS
COMM. DATED 10-30-51 PROJECT # 3696

HENRY VON OESEN & ASSOC., CONSULTING ENGINEERS & PLANNERS, WILMINGTON, N.C.

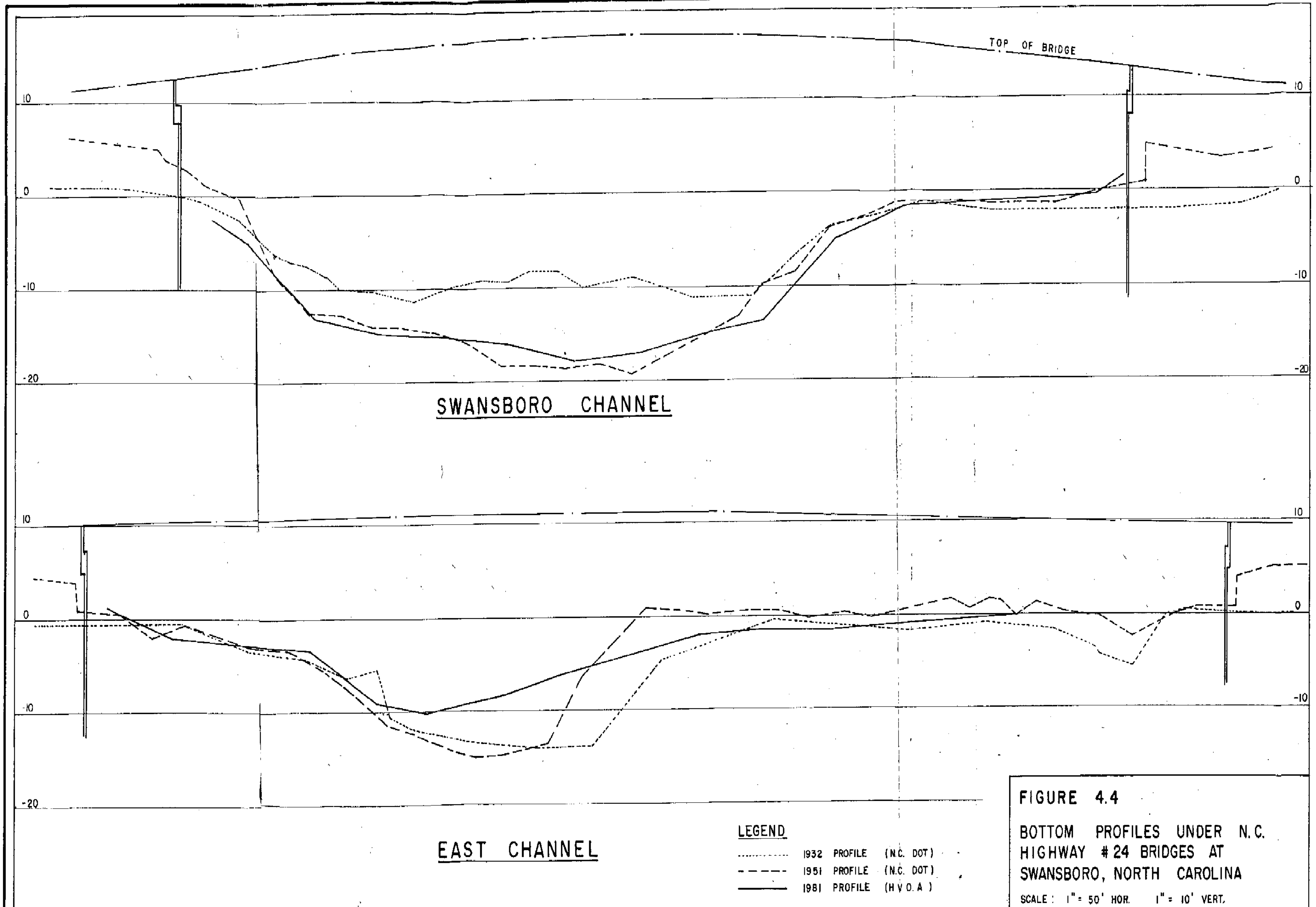


FIGURE 4.4

BOTTOM PROFILES UNDER N.C. HIGHWAY # 24 BRIDGES AT SWANSBORO, NORTH CAROLINA

SCALE: 1" = 50' HOR. 1" = 10' VERT.
M.L.W. DATUM

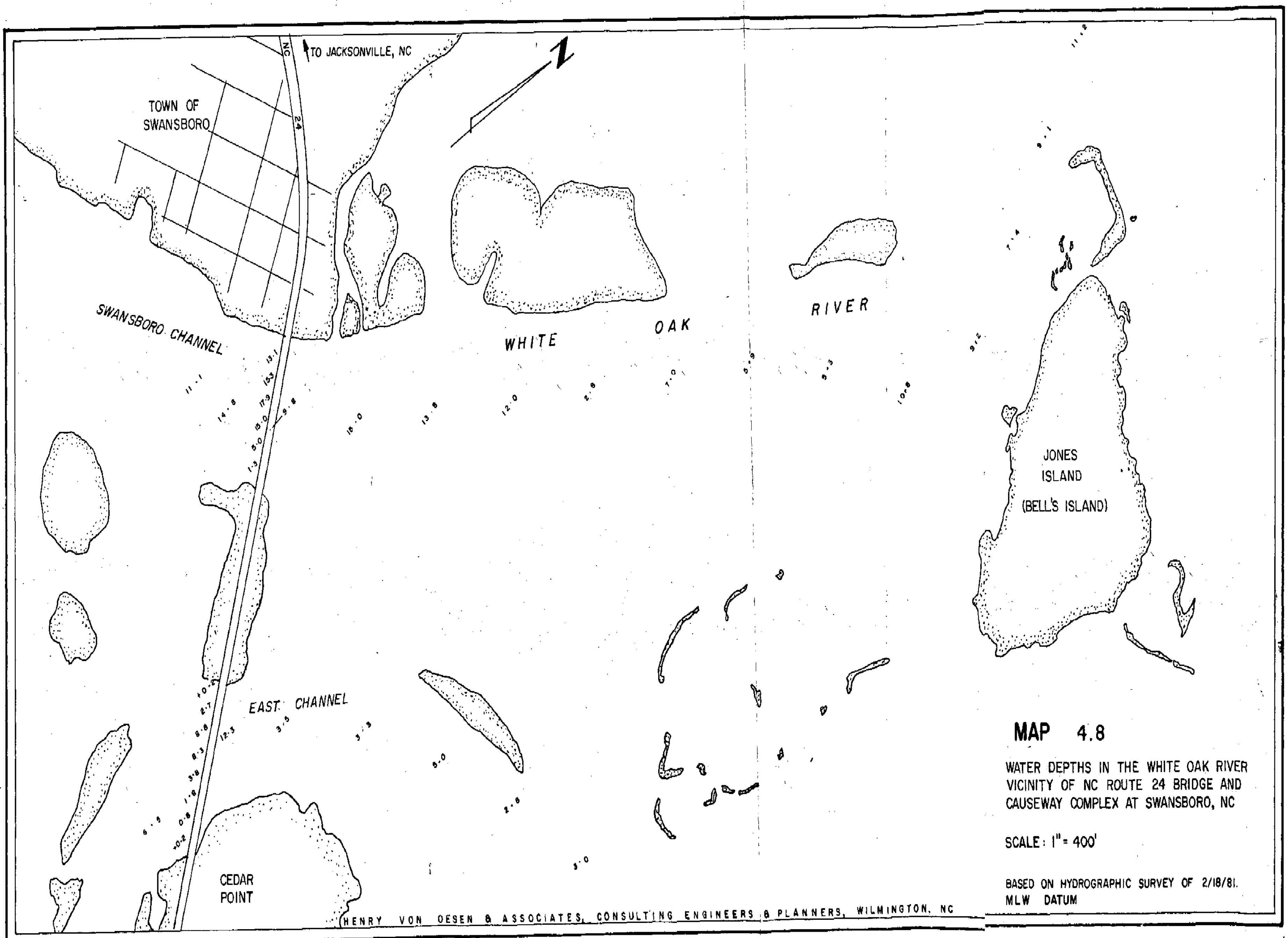
HENRY VON OESEN & ASSOCIATES, CONSULTING ENGINEERS & PLANNERS, WILMINGTON, NORTH CAROLINA

Map 4.8 shows the existing river depths in the two channels both upstream and downstream of the N. C. Highway 24 bridges. A comparison of Figure 4.3 and Map 4.8 reveals that the Swansboro Channel has increased in depth near the bridge from 1951 to the present. Water depths in the East Channel are shallow except immediately under the bridge proper where the restriction has caused a pocket-like depression. (A similar depression occurs under the bridge span over the Swansboro Channel).

In addition to the profiles, some limited current velocity measurements were made on 18 February, 1981 during a full moon tidal cycle. The current velocity readings are shown in Table 4.3. Current velocities on the ebb tide are substantially higher than the flood tide velocities due to the additive effects of the river's normal discharge flow. Differences in velocity at different depths appear to reflect the effects of the salt water wedge and/or influences of the bridge structure itself (see Figure 4.1). Flood tide velocities appear high enough to keep sediments in suspension, but some velocities are near or below 2 feet per second which would allow for sediment deposition up stream of the bridge. The lesser velocities on the flood tide may be linked with the shoaling process which is evident north of the bridge complex.

4.1.3.4 Atlantic Intracoastal Waterway

The Atlantic Intracoastal Waterway (AIWW) cuts across the White Oak River downstream of the bridge/causeway complex. This section of the AIWW is operated and maintained by the Wilmington District of the U.S. Army Corps of Engineers. The River and Harbor Act of 1927 provided authorization for a channel 12 feet deep and 90 feet wide to be constructed from Beaufort, N. C. to the Cape Fear River, N. C. This channel was completed on 23 December 1932 which means that the segment of the Waterway near the study area was completed prior to the



MAP 4.8

WATER DEPTHS IN THE WHITE OAK RIVER VICINITY OF NC ROUTE 24 BRIDGE AND CAUSEWAY COMPLEX AT SWANSBORO, NC

SCALE: 1" = 400'

BASED ON HYDROGRAPHIC SURVEY OF 2/18/81.
MLW DATUM

TABLE 4.3

CURRENT VELOCITIES
WHITE OAK RIVER AT SWANSBORO, N. C.1./

A. Swansboro Channel at West Bridge, Highway 24

Water Depth (ft)	Ebb Tide (Tide +1.1) Velocity (ft/sec)	Flood Tide (Tide +0.5) Velocity (ft/sec)
5	6.50	0.4
10	7.26	2.34
15 (near bottom)	6.16	4.01

B. East Channel at East Bridge, Highway 24

Water Depth (ft)	Ebb Tide (Tide +0.9) Velocity (ft/sec)	Flood Tide (Tide +0.7) Velocity (ft/sec)
3	5.78	4.98
6	6.21	4.23
9 (near bottom)	7.34	3.44

1./ Based on current meter studies conducted by Henry von Oesen & Associates, Inc. on February 18, 1981.

Bridge/Causeway Complex built by NCDOT. Each year, the continued maintenance of the waterway is examined and justified by the Corps based on experienced and anticipated traffic.

The Corps has subdivided the waterway into sections and units. The units are also called tangents. The area of the AIWW in the vicinity of the White Oak River consists of parts of Sections I and II and several tangents. These sections and tangents are shown on Figure 4.5. Table 4.4 shows the history of maintenance dredging for the period of 1964 to 1974 and the projected frequency of dredging for the 50-year period beginning in 1975. The zone of the AIWW nearest the White Oak River (Section I, Tangent H.) was dredged in 1971. A total of about 24,300 cubic yards of material was removed. The Corps of Engineers predicts that this area will have to be dredged only one more time in the 50-year period beginning in 1975 with another 24,000 cubic yards of material slated for removal. The infrequent dredging in this reach indicates that this area has apparently reached a relative state of equilibrium within the hydraulic complex.

In Section I, Tangent G. the Corps notes a recurring shoal where the east channel of Bogue Inlet intersects with the AIWW (see Figure 4.4 and Table 4.2). This shoal is located on the south bank of the AIWW near mile 228 and has length of 400 to 600 feet. The approximate composition of the shoal sediment is 95 percent sand and 5 percent shell. Such shoals are usually caused by the interaction of cross currents which cause current velocities to decelerate and to allow heavier sediments to drop out of suspension. The Corps projects that this shoal will need to be dredged about 13 times over the 50-year period beginning in 1975. A total of about 27,000 cubic yards of material will have to be removed each time. Thus, this segment of the reach has apparently not reached a state of equilibrium.

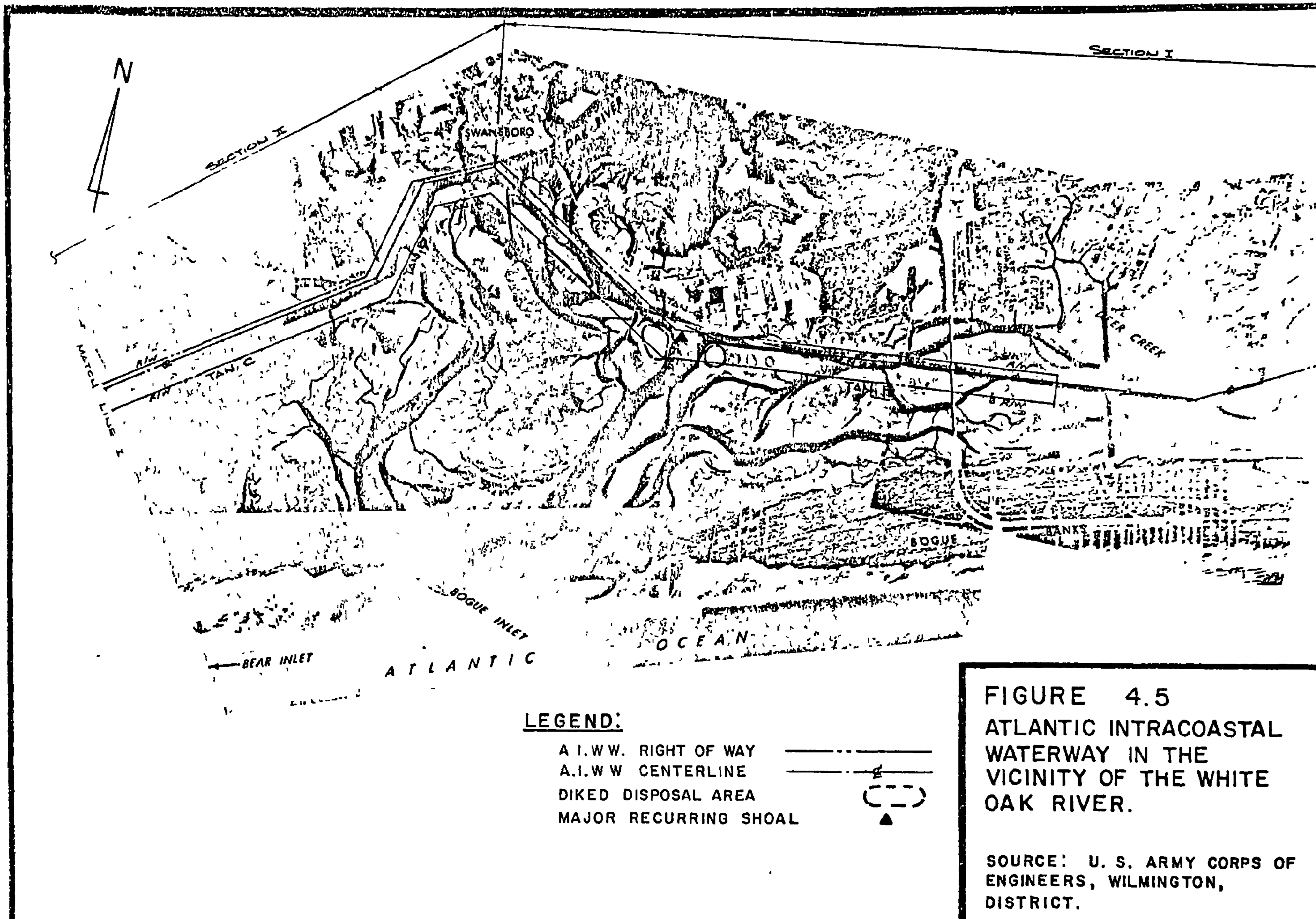


FIGURE 4.5
ATLANTIC INTRACOASTAL WATERWAY IN THE VICINITY OF THE WHITE OAK RIVER.

SOURCE: U. S. ARMY CORPS OF ENGINEERS, WILMINGTON, DISTRICT.

TABLE 4.4

Present (1963-1974) and Projected Periodicity of Maintenance and Volume of Material Removed From AIWW in Vicinity of White Oak River, N. C.1./

Location	Years Dredged 1964-74	Times Dredged Since Opening	Average Cu. Yds. Per Dredging	Est. Dredgings Next 50 Years	County	Historic Disposal3/ Practices	Current/Future Disposal Practices3/
Section 2							
Tangent C2/	1966,68,73	7	12,317	8	Onslow County	UD	D
Tangent B	None	1	0	1	Same	UD	D
Tangent A	None	1	0	1	Same	UD	D
Section 1							
Tangent H	1971	1	24,286	1	Onslow and Carteret Counties	D,UD	D
Tangent G2/	1966,71	11	27,023	13	Carteret County	D,UD	D
Tangent F	1968	2	57,996	2	Same	UD	D

1./ Source: U.S. Army Corps of Engineers, Wilmington District (February 1975) Draft EIS, Maintenance of Atlantic Intracoastal Waterway, N. C.

2./ Major recurring shoal.

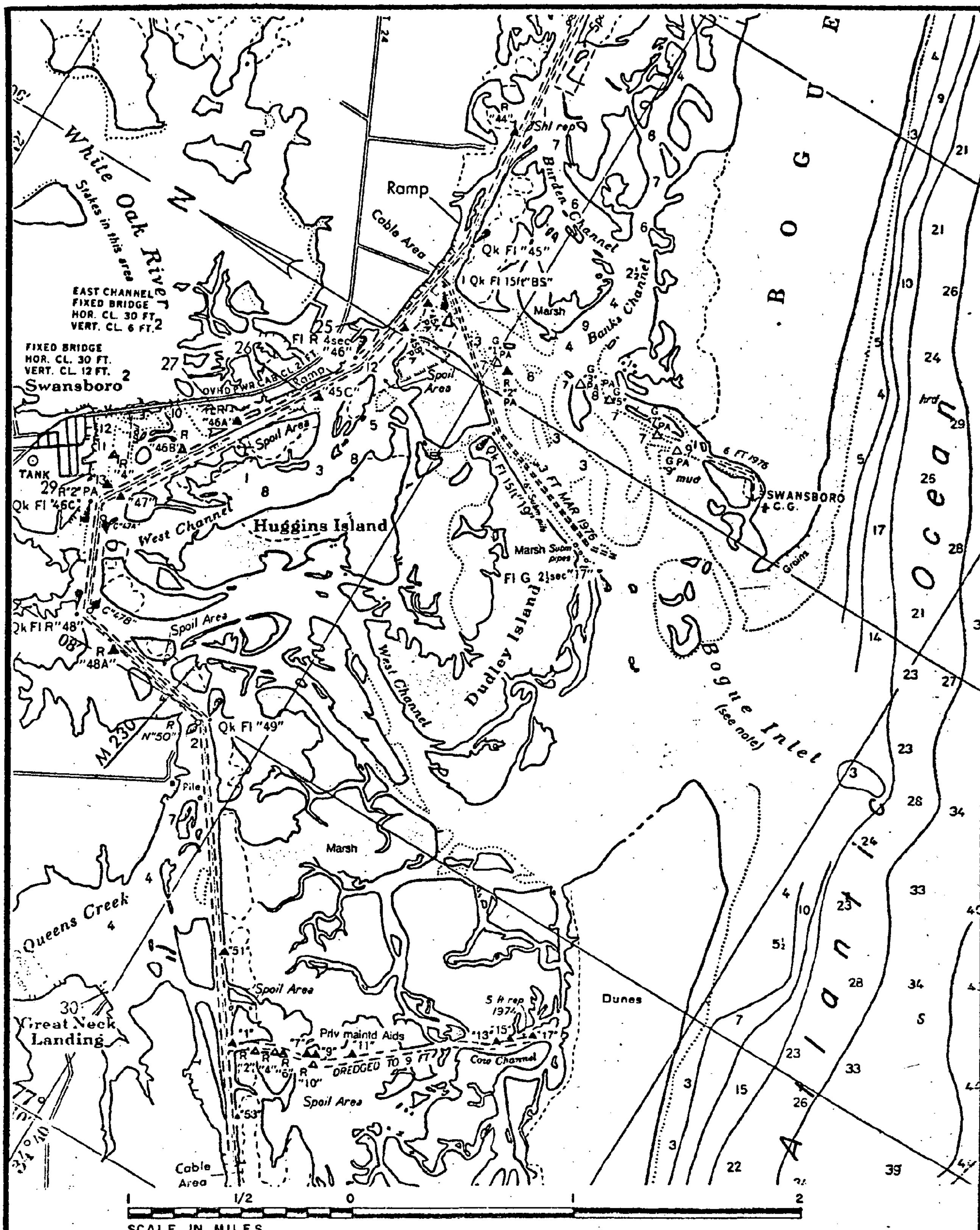
3./ Form of Disposal: D: Diked, UD: Undiked.

Therefore, it would appear from the published Corps data that the AIWW may be intercepting at least a portion of the sediment from Bogue Inlet before it can reach the White Oak River estuary north of the bridge/causeway complex. Also, discussions with Corps representatives revealed that, in their opinion, water circulation in the sections cited above increased (improved) after the construction of the AIWW due to improved flow patterns resulting from the channel deepening project.

4.1.3.5 Bogue Inlet

Bogue Inlet, one of the larger North Carolina inlets, is located at the mouth of White Oak River near Swansboro, North Carolina (see Map 4.9). It is bound on the east by Bogue Banks and on the west by Bear Banks (also known as Hammocks Beach) with Dudley Island situated directly behind the Inlet. The Inlet has two primary fresh water sources, the White Oak River and Queen Creek. The Inlet mouth is formed by two cresent shaped spits of sand. These spits are relatively unstable and are continuously in motion as is the entire gorge of the Inlet. The motion of the gorge itself is, however, much slower than that of the sand spits. The sand spits may shift radically in just a few months or even a few days under severe storm conditions, but the gorge shifts usually occur over a period of several years.

During the periods of 1938 to 1971, the net trend in migration for Bogue Inlet was to the east. The Inlet swings from east to west with the longest motion in the east direction, producing a net travel of approximately 1,300 feet. This Inlet has always been extremely wide compared to the channel flow which is from the east and the west. The 1949 photography shows two main channels which may indicate the excessive width of the gorge (see Figure 4.6 and Table 4.5).

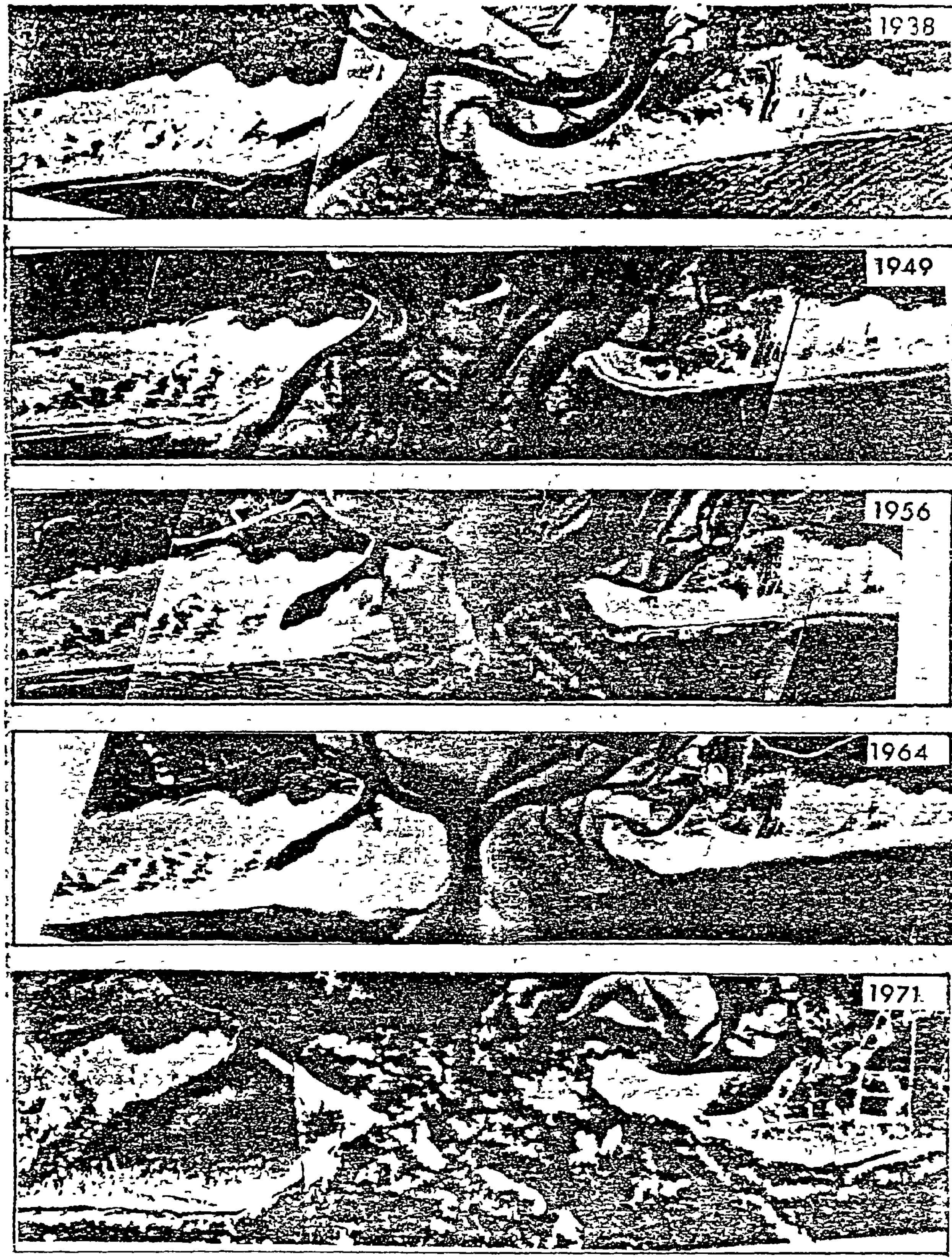


MAP 4.9
BOGUE INLET AREA

SOURCE: N.O.S. NAUTICAL CHART 11541

FIGURE 4.6

BOGUE INLET



APPROXIMATE SCALE 1" = 3333' . (1971 1" = 2000')

TABLE 4.5

CHARACTERISTICS OF BOGUE INLET[1./]

INLET CHARACTERISTICS

Year	Gorge Width (ft.)	Gorge Width Change (ft/yr)	Channel Width (ft.)	Channel Width Change (ft/yr)	Migration Of Gorge W Side (ft./yr.)	Migration Of Gorge E Side (ft./yr.)	Net Gorge Migration (ft./yr.)	Net Channel Migration (ft./yr.)
1938 1949	2532 6519	346	1059	71	75 W	270 E	97 E	284 E
1949 1956	6519 5327	-187	4246	291	6 E	185 W	90 W	219 W
1956 1960	5327 3911	-300	2206	-473	379 E	70 E	224 E	11 E
1960 1964	3911 3862	-15	698	-246	93 E	60 E	76 E	323 W
1964 1971	3862 3308	-72	1104	208	39 W	110 W	75 W	137 W

Total Gorge Migration (ft.) 1274 E   Maximum Gorge Migration (ft.) 1300 E (1938-1964)

1./ Source: Langfelder, J. etal January 1974. A Historical Review of Some of North Carolina's Coastal Inlets. Report No. 74-1, Center for Marine and Coastal Studies, N. C. State University, Raleigh, North Carolina.

In the 1972 to 73 period, Bogue Inlet underwent a large-scaled, short-term shift. The eastern spit extended a great distance out into the gorge and was cut from the main body of Bogue Banks, thus creating a new inlet.

Bogue Inlet has a migration zone stretching 1,500 feet from the edge of the vegetation on the east and the west banks. Long-term migration is relatively small, but rather large short-term movements may be anticipated in the future.

Bogue Inlet appears to be a major source of granular sediment for the lower White Oak River estuary complex. However, the quantity which reaches the Highway 24/AIWW Complex area is unknown. Discussions with the U.S. Army Corps of Engineers coastal engineers revealed that regular transport of inlet materials to the causeway area is unlikely except during major storms. In the opinion of the Corps' experts, most of the sediments in this segment of the White Oak River appear to have their origins in the original undyked spoil areas which were created when the Atlantic Intracoastal Waterway Canal was constructed and from upstream sources. However, none of these opinions can be confirmed without extensive field studies of sediment cores and their composition coupled with tracer and mathematical model studies.

4.1.3.6 Storm Surge

Storm surge due to hurricanes and extra-tropical cyclones (nor'easters) can have a profound short term effect on sediment distribution within the lower White Oak River Estuary. Under such circumstances, the Bogue Inlet Complex, AIWW and causeway areas can receive a tremendous influx of sediments due to bed load transport (see Section 4.1.2 for a discussion of this phenomenon). The heavy rainfall which is usually associated with these events can also result in heavy sediment inputs from upstream sources and additional down stream bed load transport due to the freshet condition. However, another counteractive phenomenon which may accompany these events would be an increased ebb flow (resulting from abnormally elevated tides) following the passage of the storm which would serve to transport sediments back out into the ocean and scour out channels, etc. In fact, several local residents interviewed during this study mentioned that following each major hurricane which affected the area, the channel depths in the inlet complex improved (increased in depth), only later to shoal up again in the years following the storm's passage. The movements of sediments during the recent storm events on record have not been adequately quantified in the existing body of literature on the study area.

4.1.3.7 Upstream Sources of Sediment

During periods of heavy rainfall and subsequent runoff, sediment can enter the White Oak River for transport down stream. The potential sources for such sediment were discussed in Section 3.8.2 above. However, in the absence of an extensive body of field data and a math model of the basin, it is impossible to quantify the sediment input from upstream sources. Also, the role of the Martin Marietta Quarry Lakes as potential sediment traps for the upper basin and the role of mosquito ditching in sediment transport in the lower river basin have not been evaluated. Therefore, more study of this potential source of sediment is warranted.

4.2 Fisheries Resources Depletion

4.2.1 General

As indicated in Section 3.10, existing data on landings of seafood from the White Oak River system do not seem to indicate a general depletion or dimunition of fisheries resources. However, again it is emphasized that the existing data base is very incomplete and so this conclusion may or may not be accurate. Improvements in data collection methods which were instituted by the N. C. Division of Marine Fisheries beginning in 1978 should help to confirm (or deny) this conclusion over the next few years.

Although not reflected in the seafood landing statistics, two problems related to fisheries resources depletion have been identified by fishery biologists and commercial fishermen who have an intimate familiarity with the White Oak River system. These problems are: (1) stunted growth of oysters and (2) depletion of anadromous fish stocks. Each of these problems are discussed in greater detail in the following sections.

4.2.2 Stunted Growth of Oysters

The lower White Oak River estuary has numerous intertidal oyster reefs. It has been recognized for some time that a sizable percentage of the oysters found in the extensive beds never attain the marketable size of 3 inches. In order to recover some of this unused resource, some limited private and State interests have transplanted some of these "stunted" oysters from the White Oak River to beds in the nearby Newport River where they have attained marketable size.

During the Summer of 1978, the Duke University Marine Laboratory sponsored a student originated studies project on the factors influencing the stunted growth of oysters in the White Oak River. This Duke University student study team, funded by a grant from the National Science Foundation, utilized an interdisciplinary approach to the problem. The disciplines included biochemistry, ecology, water chemistry and physiology. Their findings were set forth in an unpublished report entitled, "Factors Influencing Stunted Growth of the Oyster, Crassostrea virginica, In the White Oak River, North Carolina". (See Bibliography, Section 8). A summary of the results of their study follows:

A. Water Chemistry

(1) Determinations of several water quality parameters, as well as, the amount and type of suspended sediments, current speed, salinity and temperature revealed few differences between stunted and normal sites or between the White Oak River and other nearby coastal rivers, except for the

fact that (a) current speeds were significantly different from site to site, (b) mean temperatures are higher for summer months in the White Oak River than in other nearby estuaries and (c) the salinity gradient appears wider than is typical for other local rivers thereby inferring a larger percentage of fresh water inflow resulting in a wider range of nutrient values.

(2) Except for the temperature, the White Oak River appears well-suited to oyster growth. Consistently high summer temperatures may contribute to stress on oysters throughout the river.

B. Ecology

(1) The stunted growth is apparently not caused by the oyster pests, Polydora sp. (a polychaete worm) or Dermocystidium marinum (a coccidian fungus), due to the fact that their relative numbers did not correlate with the size differences of oysters at the respective sites.

(2) Extensive sampling at each site revealed:

a. A strong linear relationship between density (number of oysters/square meter) and oyster size (height in mm).

b. Stunted sites showed a much greater degree of mortality.

c. The population size structure for each site revealed that the stunted sites have a higher degree of spatfall while the normal sites have a greater number of larger oysters. None of the sites selected for study, however, support significant numbers of marketable oysters.

d. Observations of cages deployed to each site containing juvenile oysters from a homogeneous population revealed that growth (over a 3-month period) was significantly less for stunted than normal sites.

C. Physiology

A current chamber was designed and constructed to simulate three current speeds common to the experimental sites in the river. The effect of current speed was determined on the growth of juvenile oysters from a homogeneous population. It was discovered that oysters in fast currents grew significantly less than those in medium currents with slow currents showing intermediate growth rates.

D. Biochemistry

(1) Although the growth rate of oysters is influenced by several factors, the immediate cause for the phenomenon of "stunting" as observed in the White Oak River is early mortality. No oysters of marketable size are found at the stunted sites. This strongly implies that the oysters at the stunted sites are dying before they are big enough to be taken.

(2) The factors responsible for mortality and slow growth at the stunted sites appear to be density and current velocity. High summer temperatures serve to amplify the stresses on the oysters due to the fact that at higher temperatures the pumping and metabolic rates of the oysters decrease. Also, conditions favoring high spat set assure that density associated stress is continuously felt and self perpetuated.

(3) The factors discussed above combine to produce a highly stressful environment in which young oysters can survive; although they are less viable than their normal site counterparts. As the metabolic demands of the oyster increases with size and the ability to compensate is diminished, the animal becomes less viable and eventually dies before reaching full size.

4.2.3 Depletion of Anadromous Fish Stocks

Anadromous fishes have suffered a general decline in relative abundance throughout the coastal region of N. C. and all along the Atlantic seaboard. This decline has been variously attributed to pollution (mainly from certain organic compounds which disrupt the reproductive processes), stream channelization and the construction of dams or a combination of these factors. This general decline is not reflected in the landings of finfish from the White Oak River because of the minimal commercial effort devoted to harvest of anadromous fishes. The N. C. Division of Marine Fisheries (1975) reported that the White Oak River supports a recreational dip net and gill net fishery mainly for river herring. Fishing is primarily confined to the Martin Marietta Quarry Lakes at Belgrade and may involve between 15 to 20 local people per night with catches of 50 to 100 pounds per person during the peak of the herring "run". The incidental catches of anadromous fish by commercial fishermen is minor, with little apparent value to the White Oak River fishery.

In view of the above, it would appear that the depletion of anadromous fish stocks, if it is indeed occuring, is not causing any alarm amongst commercial fishermen. In fact, certain anadromous fish potentials appear to be underutilized at the present time.

4.3 Pollution

As indicated in Section 4.2.3 above, various forms of pollution are causing problems in the White Oak River system. The most important of these problems is the closing of shellfish harvest areas due to high coliform counts. The nature of this problem has been clearly defined and discussed earlier in this report (see Sections 3.7 and 3.8 above).

SECTION 5: PROPOSED ACTIONS RELATED TO EXISTING PROBLEMS

Based on the information and findings in the preceding sections of this report, suggested actions related to identified problems are outlined in the following paragraphs.

5.1 <u>Sedimentation</u>

5.1.1 <u>Non-Structural Actions</u>

5.1.1.1 <u>Additional Study</u>

As indicated previously, general conclusions may be reached regarding the causes, sources and effects of sedimentation in the White Oak River. It is strongly presumed that the principal source of sediments which comprise the extensive shoals north of the N. C. Highway 24 Bridge/Causeway Complex are the original unconsolidated spoil areas which were created during the construction of the AIWW. Little information is available related to what contribution, if any, the materials from the mouth of Bogue Inlet and materials from upstream sources have to the overall sedimentation problem.

Additional study of the problem should take the form of a combined field data collection effort and a detailed mathematical model study of the riverine/estuarine complex. The specific nature of the field investigations and subsequent math model studies have been identified by NCSU scientists based on meetings and discussions of the problem and desired objectives. The suggested program is as set forth in Appendix C of this report. Briefly the NCSU modeling study will be used to numerically analyse the hydrodynamics and the associated pollution and sediment transport. The numerical analysis of the area will require the following inputs from field data collections of cross-sections of the river coupled with measurements of water level fluctuations, velocity of flow, density variations, salinity and sediment and pollutant concentrations at several sampling stations.

In the regions of the river where the flow can be considered one-dimensional, i.e, along the axis of the river such as near Webb Creek, a one-dimensional finite element mathematical model will be used. This model will then be coupled with a two dimensional math model which will be used for regions of the river where the width is great enough to also cause predominant flows at right angles to the axis of flow.

The proposed modeling studies should help to define the following:

(1) The role of the Martin Marietta Quarry Lakes as potential sediment traps.

(2) The contributions of sedimentation of the river from agricultural and silvicultural practices.

(3) The contribution of sediment from mosquito ditches.

(4) The source(s) of granular sediments in the lower river estuary.

(5) The specific nature of the salinity of gradients of the river.

(6) The potential effects of any structural remedies or improvements on sedimentation.

(7) Sources, concentrations and fate of pollutants.

5.1.1.2 Expansion of Ongoing Studies of Bogue Inlet and the AIWW by the U. S. Army Corps of Engineers

The Wilmington District of the U.S. Army Corps of Engineers is in the process of completing a study of Bogue Inlet which was authorized by congressional resolution. The Corps has accumulated considerable data on Bogue Inlet and adjacent waters as a result of this project. Due to the fact that spoil from the construction of the AIWW has been tentatively identified as a primary source of granular materials in the shoals located north of the North Carolina

Route 24 Bridge/Causeway Complex, it may be possible for the Corps to expand this study to study the matter in question.

The interjection of the Corps' expertise, manpower, and physical resources into a study of sedimentation problem in the lower White Oak River as they relate to construction and maintenance of the AIWW and Bogue Inlet would contribute greatly to fixing cause and effects relationships. If it is found that the Federal projects are (or have been) major contributions to the problem, then additional remedies may be recommended.

5.1.2 Structural Solutions

5.1.2.1 Shallow Dredging of Sediments

Upon completion of detailed field investigations and math model studies, the extensive shoal areas north of the N.C. Highway 24 Bridge/Causeway Complex could be removed by dredging, if such action is found to be economically justified. It is presumed that the shoals are now in a state of relative equilibrium and, if removed from the hydraulic complex, they may not reoccur. This is due to the presumption that the source of these materials was primarily from the dredging associated with the AIWW and not from Bogue Inlet or upstream sources.

Before this structural manipulation of the ecosystem is undertaken, there should be an addressment of (1) economic justification, (2) environmental effects including benefits and risks, (3) salvage of seafood resources (oysters and clams) and (4) identification of suitable spoil areas.

5.1.2.2 Creation of Additional Flow Channel(s)

The construction of the AIWW and the N.C. Highway 24 Bridge/Causeway Complex resulted in pronounced changes in the hydraulic regime in the lower river as is documented in Section 4.1.3 above. The effective width of the river was reduced and one channel was eliminated by the dredge and fill activities. These actions were conducted with a minimum of prior assessment of impacts on mitigative measures were undertaken at the time of construction and it is dubious whether such "after the fact" action would now be appropriate.

However, if more detailed studies show such to be appropriate, environmentally desireable and economically feasible, it would be possible to partially restore the flow regime which existed prior to the early 1930's. This could be done by reconnecting the upper river embayment north of Cedar Point (Hill's Bay) with the AIWW and the upper Bogue Inlet complex by the installation of large pipe conduits emplaced under N.C. Highway 24. The specific area where such an interconnection cound best and most logically be constructed is shown on Map 5.1.

The proposed location for the connecting conduit would utilize an existing dredged channel on the north side of the causeway and an existing marina basin on the south side of the conduit. Prior to any construction actions, the following items would need to be addressed:

(1) Flow channel dimensions and flow requirements.

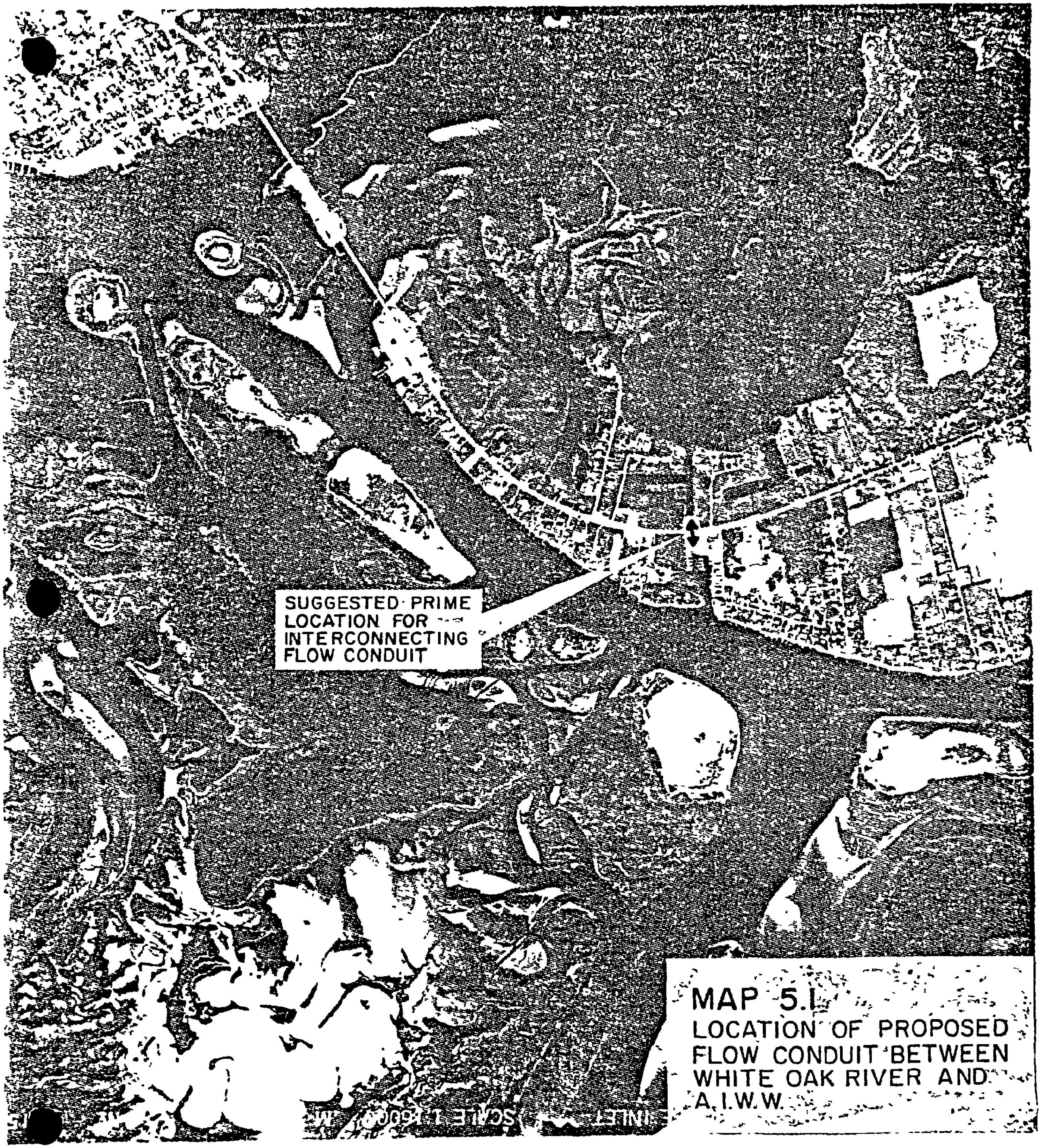
(2) Beneficial and adverse environmental impacts of altering the flow regions and salinity gradients in the estuary.

(3) Impacts on the marina complex.

(4) Sociological desireability of the project.

(5) Movement of potential pollutants from the marina basin and area septic tanks to the vicinity of White Oak River shellfish beds.

(6) Potential for shoreline erosion on developed properties caused by normal diurnal flows or severe storm events (hurricanes and nor'easters).



MAP 5.1
LOCATION OF PROPOSED FLOW CONDUIT BETWEEN WHITE OAK RIVER AND A.I.W.W.

5.2 Fisheries Resources Depletion and/or Underutilization

5.2.1 Stunted Growth of Oysters

5.2.1.1 Non-Structural Solutions

A. Additional Study

The report entitled "Factors Influencing Stunted Growth of the Oyster, *Crassostrea virginica*, in the White Oak River, North Carolina" by the Duke University Marine Laboratory study team, which was discussed above in Section 4, suggests some additional experiments to confirm their findings. These suggested experiments are repeated here and include the following:

(1) In order to verify the correlation of density and growth, as well as mortality, a typical stunted oyster reef can be selected for manipulation. Clear cut a 10 x 10 meter (33 x 33 foot) section of the reef. Then uniformly distribute small oysters at some low density, say 10 to 20 oysters per square meter (1 to 2 oysters per square foot). As a control, tag oysters of a similar size on an adjacent section of reef, leaving them at the natural density. Compare the growth and mortality of oysters subject to each regime over a 2 to 3 year period.

(2) Check the recuperation of different age classes of the stunted oysters by transferring several hundred each of fresh spat, first year, and second year oysters from a reef like those near mid river opposite Stevens Creek (see Map 3.5 for location) to a suitable site up river or down river. This experiment is designed to reveal the most advantageous age for transplantation.

(3) Deploy setting plates to verify the setting potential of oyster spat throughout the river.

(4) Initiate a well-coordinated study aimed at showing the changes of metabolic fitness with time. This would include measuring the pumping

rate/metabolic rate along with the glycogen, lipid and protein changes associated with aging. The Duke scientists surmised that young oysters have a higher pumping rate/metabolic rate ratio. This study might indicate a crucial age and season at which an oyster is especially susceptible to mortality. If carried out at different temperatures, it would verify the Duke scientists' assumption that elevated water temperature is a major contributor to poor fitness and early mortality of oysters in natural waters of North Carolina.

B. Oyster Replanting Program

The above referenced Duke University Marine Laboratory study also recommended a replanting program for the stunted oysters. In recognition of the fact that these stunted oysters are potentially marketable, the Duke scientists suggested that they be transferred to areas which have more in common with ideal conditions described below:

(1) A sandy bottom, covered with a few inches of mud to prevent the sand from shifting and burying the oysters.

(2) Salinity in the range of 15-25^{o}/oo. Although oysters will grow well above 25^{o}/oo, the incidence of predation by Urosalpinx (the oyster drill) becomes a severe detriment.

(3) Medium range (5-50 cm/sec or 0.16 to 1.6 ft/sec) current speed, enough to allow for removal of wastes, but not so much as to hinder growth.

(4) Although oysters can grow well intertidally, it is best to avoid rivers like the White Oak which are almost uniformly shallow. High water temperature and increased effects of tidal currents result. Estuaries of mean depth greater than 3 feet with effective flushing by ocean tides are ideal. (The Newport River has been successfully used in the past as a grow

out area for White Oak River oysters).1./

(5) Use as low a density as possible. Spreading the oysters out is probably the key to effective use of White Oak River oysters.

(6) Sufficient food supply - this is a difficult parameter to measure without access to a laboratory. In general, most North Carolina estuaries have sufficient food for oysters attain to marketable size.

(7) If spat set proves to be very high, it becomes essential to "work" the oyster bed in order for good yield to continue. Neglect in this area will eventually result in overcrowding and a return to conditions found at "stunted" sites in the White Oak River.

In addition to the above points, the Duke Marine Laboratory study team concluded as follows:

"Thus, we view the "nubben" oysters of the White Oak River as anything but useless. They will continue to exist as a concentrated but ignored food resource until such time as it can be brought to the attention of fishermen and citizens that with proper deployment, North Carolina oysters can once again contribute to a tasty and nutritious diet."

5.2.1.2 Structural Solutions

A. Shallow Dredging to Create A More Favorable Habitat for Oysters

The above cited Duke University Marine Laboratory study indicates that the shallowness of the White Oak River estuary is a contributing factor to the stunted condition of the oysters in the river. Therefore, it is submitted that a carefully planned and executed program of shallow dredging of certain areas of

1./ Also, the N.C. Division of Marine Fisheries has successfully used public oyster management areas in the upper estuary for grow-out of relayed oysters (see Map 3.6 for locations).

the river will enchance the productivity of the oyster reefs. Such a program should be instituted in conjunction with the relaying program recommended under non-structural solutions. The shallow dredging would also be coordinated with any recommended structural actions required to correct the shoaling in the estuary. (See Section 5.1.2.1 above). Before a massive program is undertaken in this area, a test zone in the river could be selected to test the overall feasibility of the proposal. The environmental effects (both beneficial and adverse) and the economics of this potential solution would have to be carefully studied prior to any actual work.

5.2.2 Underutilization of Clams In Polluted Areas

As indicated in Sections 3.9 and 3.10, hard clams are an important resource of the White Oak River which are currently underutilized. Recent increases in prices for clams have stimulated an increased harvesting effort mainly on the part of some Long Island, NY shellfishermen who have settled in Swansboro and local shellfishermen from the Maysville and Sneads Ferry area of the New River. The former have employed wide multitong "bull rakes" imported from the north to hand tong clams. The latter have used locally constructed narrow clam rakes for hand tonging and some have employed more sophisticated hydraulic dredges to harvest clams.

The N.C. Division of Marine Fisheries' Management Section personnel believe that there are significant hard clam resources in polluted areas which could be harvested if they were removed to clean areas for self- cleansing and subsequent harvest. Current regulations and lack of funds have prevented both the N.C. Division of Marine Fisheries and private interests from exploiting this under-utilized resource. Relative to existing regulations, N. C. Division of Marine Fisheries' personnel explained that there is currently no closed clam season, nor is there a convenient time to close the season on a statewide basis. The late fall, winter and early spring months are times of peak harvest of clams certain full-time commercial fishermen. In the summer months while the full-time commercial fishermen normally divert their efforts to other fisheries such as shrimping, hand rakers (full time commercial), school and college students and retirees on fixed incomes comprise the bulk of clammers harvesting the resource. Thus if a closed season were proclaimed in mid summer, the hand rakers, students and retirees would lose needed income.

While the Division of Marine Fisheries issues the proclamations for opening and closing of seasons, the Shellfish Sanitation Office is responsible for determining that the shellfish are suitable for human consumption and for regulating such openings or closings. At their current levels of funding these agencies would be hard pressed to conduct the necessary biological tests or to enforce the closings much less relay the shellfish.

The solution to this problem lies, in part, in developing new regulatory procedures for handling clams. Two alternatives are possible:

(1) <u>Alternative A (A Statewide Closed Clam Season)</u>

Under this plan, a closed clam season of suitable duration would be proclaimed statewide. The months of May, June and July have been suggested by several fishermen as the "best time" to close the season on claims due in part to the fact that this period is the peak development time for seed clams. Also, the overall commercial harvest of clams usually falls off due to diversion of interest to other fisheries (shrimping) and a usual decline in market value due to the introduction of clams from other areas, mainly Long Island Sound, etc. During this closed period, no clams could be marketed statewide thereby removing any incentives for illegal harvesting. During this time clams from polluted areas could be moved to clean areas by the N. C. Division of Marine Fisheries and/or private interests by permit.

To mitigate any adverse economic impacts on certain user groups, clams could be sold to shellfish dealers having private clam gardens. These clams would be placed in the gardens under the supervision of the dealer and the harvesters would be renumerated accordingly. The harvesting of clams from polluted areas would be halted 15 days prior to the reopening of the season to permit the clams to cleanse themselves of pollutants. After the 15 day waiting period, the season would be reopened statewide thereby permitting normal harvesting and marketing to resume.

The advantage of this alternative is that it represents a minimal level of law enforcement effort due to the fact that anyone selling clams for human consumption during the closed season is immediately obvious and subject to legal action. The entire coastline would not have to be policed for "midnight raiders", as unscruplious clam thieves are often called.

The major disadvantages of this alternative are (1) it could create severe economic hardships to certain user groups (hand tongers) and (2) the season for relaying clams conflicts with the season for relaying oysters by the N. C. Division of Marine Fisheries.

(2) <u>Alternative B (Local Closed Clam Areas)</u>

Instead of proclaiming a statewide closed clam season, specific bottomlands in the White Oak River could be designated as public clam management areas similar in concept to public oyster management areas. Polluted clams could be relayed to these areas which could be closed by proclamation until tests show that the clams have purged themselves of pollutants and are ready for human consumption. Then the area can be opened for harvesting by proclamation.

The advantage of this alternative are that the closure would be of relatively short duration (less than 30 days) and of limited geographic area, that is, applicable to small specific areas within the White Oak River. Therefore, the impacts on specific user groups (hand tongers) or fishermen from other areas would be lessened or eliminated entirely.

The major disadvantage to this alternative is that the closed areas would have to be policed constantly. Local fishermen indicate that nighttime thefts from the closed beds filled with clams could be a common occurence. Thus, the implementation of this alternative might require a substantial increase in funds and manpower for the N. C. Division of Marine Fisheries to enforce the closures. However, the N. C. Division of Marine Fisheries personnel believe that these adverse conditions can be mitigated by careful selection of areas used for the relocation of the polluted clams and/or by closing the clam season in Onslow, Jones and Carteret Counties. If clams are relocated to areas where daylight or nighttime thefts would be obvious such at the end of roads or adjacent to the Route 24 bridges, enforcement efforts would not have to be increased substantially. Also, if the sale of clams in the counties surrounding the river was banned, then the likelihood of polluted clams reaching the marketplace is reduced.

The selection of either alternative A or B would be based in part on public input from a series of public hearings conducted statewide by the N. C. Division of Marine Fisheries.

The Division of Marine Fisheries currently lacks the personnel and financial resources required to operate the hydraulic dredge plants which would be required to conduct a clam relaying program in the White Oak River. However, private interests, i.e. local commercial fishermen, have the ability and the equipment to harvest the clams. With the proper incentives and proper supervision of the N.C. Division of Marine Fisheries, these interests could be paid a small stipend (an amount in the range of \$1 to \$5 per bushel of clams has been suggested) to go into the polluted beds, remove the clams and replant same in unpolluted public or private management areas which have been closed. Subsequently, after a period of time, these interests could be allowed to harvest and market the clams from the same management areas once they have been opened by proclamation.

Funds to conduct and manage this program could come from several sources. For example, Onslow, Jones and Carteret Counties may wish to provide funds to sustain the program in an effort to stimulate the local economy. Federal funds to aid in the development of the program and to create jobs could come from the Economic Development Administration (EDA) or from the Comprehensive Employment and Training Act (CETA)[1]. These funds, combined with the willingness and devotion of private interests, could result in a workable solution to the problem of underutilized clam resources in the White Oak River.

5.2.3 Depletion and Underutilization of Anadromous Fish Stocks

Certain anadromous fish such as Striped bass (rockfish) and American shad have suffered depletions due to several causes (see Section 4.2.3). Several State and Federal agencies are probing the causes of their decline. Little commercial fishing effort is now devoted to these species. On the other hand, river herring seem to enjoy good population levels in the White Oak River. The N. C. Division of Marine Fisheries believes that the herring stocks could be further exploited as crab bait. Thus, with a little effort landings could be increased from less than 1,000 pounds to several tons annually.

Therefore, the solution to this problem appears to be an educational campaign amongst commercial fishermen and a general awareness of the use of herring as bait by commercial crabbers in the area. Such an educational effort

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1./ The future of these funding sources is uncertain as of this writing.

could be conducted by UNC Sea Grant through their regional advisory agents.

herring as bait by commercial crabbers in the area. Such an educational effort could be conducted by UNC Sea Grant through their regional advisory agents.

5.3 Pollution

5.3.1 Point Sources of Pollution

5.3.1.1 Non-Structural Solutions

The Division of Environmental Management of the N.C. Department of Natural Resources and Community Development is the agency which regulates point sources of pollution. All sources must comply with provisions of their permits and must monitor their effluent discharges. Thus, the State has a good handle on point source discharges and adequate mechanisms exist to insure compliance with existing regulations.

Future increases in population in the White Oak River Basin could result in additional point sources of pollution and possibly increased closings of shellfishing waters. Recognizing the importance of shellfishing to the economy of the area, NCDEM should encourage the use of alternative technologies, i.e., non-discharge alternatives for disposal of human wastes. Alternatives such as land application or subsurface disposal of wastewater will help preserve the surface waters for shellfishing for future generations.

County and Town planning boards in the region can also do their part by insisting on high engineering standards for sewage treatment and disposal for housing subdivisions and industries which may locate within their jurisdictions.

Thus, strict enforcement of existing laws should help to solve the problem of point source pollution.

5.3.2 Non-Point (Diffuse) Sources of Pollution

5.3.2.1 Non-Structural Solutions

A. Further Study - Mathematical Modeling

While it is known that non-point sources contribute pollutants to the White Oak River, the exact locations and extent of the contribution is unknown at this time. Mathematical modeling studies of the river and its tributaries could help to form a picture of what is happening basin-wide. Of particular concern is the source of pollution which has resulted in the closing of the upper river (above Godfrey Branch) to shellfishing (see Map 3.5). A math model program complimented by field investigations has been defined in Section 5.1.1.1 above and in Appendix C. The development of a basin specific model will help to enhance basin pollution control measures.

B. Soil Conservation Services Watershed Programs

Any future study of non-point sources of pollution should involve the resources and expertise of the United States Department of Agriculture (USDA), including its component agencies, the Soil Conservation Service (SCS), the Economics, Statistics and Cooperative Service (ESCS) and the Forest Service (FS). Authorization for USDA to participate in any study of this nature is provided in Section 6 of the Watershed Protection and Flood Prevention Act of the 83rd Congress (Public Law 83-566, as amended). This legislation authorizes the Secretary of Agriculture to cooperate with other Federal, State and local agencies in their investigation of watersheds and river basins to develop a coordinated program. The Tar-Neuse River Basin Main Report (October, 1980) identifies an application for a Public Law 83-566 watershed project on the upper White Oak River basin. Some work was begun on the project in the late 1960's and early 1970's but was subsequently suspended. Based on the information provided in this current study of the White Oak River, there appears to be sufficient justification for a revival of this application with an expansion to include the lower river basin as well. A study of this nature could eventually evolve into recommendations for specific structural solutions to the problem.

5.3.2.2 Structural Solutions

A. Central Wastewater Collection and Treatment Systems

Effluent residuals from septic tanks are clearly suspected of causing pollution problems in the White Oak River basin as documented in Sections 3.7 and 3.8.2.5 above. This pollution has resulted in the closing of many acres of productive shellfish grounds as depicted on Map 3.5. As development in the basin increases, the septic tank effluent problem is certain to increase.

Certain mechanisms already in effect can provide structural solutions for this problem. For example, the Swansboro Area 201 Facility Plan provides overall plans to provide central sewers in certain developed areas west of Swansboro along Highway 24 which areas are now served by septic tanks. These areas are programed to ultimately connect to the Swansboro Municipal Wastewater Treatment Facility at Foster's Creek.

The selected facility plan for the Carteret County segment of the planning area falls within the selected regional plan called "Plan C-1" in the 201 Plan. This plan calls for the future construction of two separate facilities, one to serve the Town of Cape Carteret and environs on the mainland and one to serve West Bogue Banks including Emerald Isle, Indian Beach and Salterpath. However, for the present, the plan calls for the continued use of individual privately owned septic tanks and small aerobic treatment systems due to the fact that publicly owned central sewer systems are now not economically feasible to construct. The 201 Plan recommends that the plan be re-examined by local and State authorities on a regular basis to determine when it would economically feasible to implement. When it becomes economically feasible to build wastewater treatment facilities for West Carteret County, the local governments have the mechanism in the form of Plan C-1 to pursue the project.

When economic feasibility is assured, the selected plan for Cape Carteret provides for the construction of an aerated lagoon - land disposal system treatment facility located on private property northeast of the Star Hill Golf Course. The facility is projected to have an initial design capacity of 0.3 MGD and will include effluent storage, pumping and irrigation equipment. The facility will occupy an area of 80 acres consisting of treatment units, a 200 ft. buffer zone and "wetted" land area of 45 acres. Crops grown on the site for nutrient uptake will include Coastal Bermuda grass overseeded by Winter Rye during the winter season. The plan calls for some additional planning in the form of a soil and hydrologic survey of the disposal site before the design of the system is begun. The selected plan also calls for the construction of ancillary collection sewers and main interceptor and pump station to "feed" the facility concurrent with the facility construction. This collection system could be extended to serve the Cedar Point area when necessary.

Likewise, when it becomes economically feasible to construct a wastewater treatment facility on West Bogue Banks, the facility will be constructed on a 10 acre site at Emerald Isle in the vicinity of the Cameron Langstone Bridge. The treatment facility will have an initial design capacity of 1.3 MGD and will employ the oxidation ditch modification of the extended aeration-activated sludge process. Treated and disinfected effluent will be pumped to the beach margin via a force main and will be discharged to the Atlantic Ocean by an outfall and diffuser system of suitable length. A collection system serving the developed areas of the Banks is also a part of the plan.

In the areas not covered by the comprehensive Swansboro Area 201 Facility Plan other mechanisms are available for dealing with the septic tank pollution problem. When reviewing plans for developments and subdivisions, local planning boards can insist on central sewers and package treatment systems with land application of effluent in lieu of septic tanks particularly for new high density development contingent with tributary streams leading to the White Oak River. When appropriate, these systems later can be interconnected with existing or planned municipal systems. Prudent long range planning in the case of wastewater disposal will prevent future crisis situations and additional losses of shellfish growing areas to the spector of fecal pollution.

B. Improved Septic Tank Installation Practices

In many areas within the White Oak River Basin, individual on-site wastewater disposal systems (septic tanks) will continue to be used for the treatment and disposal of wastewater. Optimal operation of these systems is in large part governed by proper installation techniques. Rules and regulations[1./] governing the installation of septic tanks are established the by North Carolina Department of Health Services, Environmental Health Section based in Raleigh, N. C. These rules and regulations are enforced by County Sanitarians. Strict Adherence to these regulations will ensure that each septic tank installation is preceded by a soil test to determine suitability of the soil to adsorb treated effluent. Where soils are unsuitable for standard nitrification fields, modified systems such as mounds or shallow low pressure injection systems may be

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1./ Laws and Rules For Ground Absorption Sewage Disposal Systems of 3,000 Gallons or less Design Capacity Section 0.1900 of the N. C. Administrative Code, Title 10 Department of Human Resources, Chapter 10 Health Services, Environmental Health, Subchapter 10A Sanitation. July 1, 1977 as amended.

suitable. Each installation must be treated on a case-by-case basis to insure compliance with standards and to avoid environmental harm. Technical information on the proper design of onsite wastewater treatment and disposal systems may be found in the EPA manual entitled Design Manual, Onsite Wastewater Treatment and Disposal Systems October, 1980. U.S. EPA, Office of Research and Development, Municipal Environmental Research Laboratory, Cincinnati, Ohio.

SECTION 6: RECOMMENDATIONS FOR ADDITIONAL STUDY

One of the stated objectives of this investigation and report was to identify specific problem areas that can only be resolved by broader based or more extensive study than was attainable with the limited resources available for this overall analysis of problems in the White Oak River basin. While it is recognized that "overstudying" an area can be an exercise in redundancy, it is felt that in this case specific problems within the basin can be resolved by additional investigations that will confirm and suggest implementation measures for corrective actions recommended.

Finally, the White Oak River region represents a relative undeveloped but typical small Coastal Plains river basin area which, if proper plans and models are developed and implemented, can serve as a prototype for similar basin areas throughout the southeastern coastal region of the United States. Therefore, based on the review of the present state of knowledge on the conditions and problems of the White Oak River and the proposed solutions to the problems, the following recommendations are made for additional study:

(1) A study to develop a mathematical model of the White Oak River. The math model will be used to define recent changes, to predict future changes caused by natural and man made impacts on the river system and to confirm the validity of solution alternatives suggested in this report. This study could best be undertaken and performed under the auspices of the UNC-Sea Grant Program.

(2) A study by the N.C. Division of Marine Fisheries of the shellfish resources in the White Oak River. The end product of this study will be a shellfish bottom inventory and map of the shellfish beds in the river.

(3) Expansion of the U.S. Army Corps of Engineers Bogue Inlet Study to determine the origin, cause and appropriate corrective actions for control of shoaling problems north of the N.C. Highway 24 Bridge/Causeway Complex.

(4) Additional study of the stunted oyster problem by Duke University Marine Laboratory personnel. This study should fill in the gaps of the previous study and recommend further corrective actions as indicated in Section 4.2.2.

(5) A study of the sources and quantities of sediments and pollutants in the upper river. This study should be a joint effort by the U.S.D.A. and NCDEM under the auspices of the PL83-566 program.

Further details on these and other recommendations are found in Section 7 following.

SECTION 7

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

WHITE OAK RIVER SYSTEM STUDY

(A Plan Of Action For The White Oak River)

HENRY VON OESEN AND ASSOCIATES
CONSULTING ENGINEERS
AND PLANNERS

SECTION 7: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 Summary and Conclusions

The preceding study of the White Oak River basin was conducted to define existing conditions and problems and to suggest recommendations for further study along with proposed non-structural and structural solutions to identified problems. The following summarizes the major conclusions reached in this investigation and presents a plan of action for the White Oak River wherein each specific recommendation is identified and estimated costs are suggested for completion of the recommendation. While certain identified problems must receive additional study, some actions can be undertaken immediately with little or no additional delay.

The first major conclusion of this study is that the water depths in the lower White Oak River have decreased during the past century, particularly since the major construction projects of the AIWW and N.C. Route 24 Bridge and Causeway which occured in the early 1930's. The redistribution of unconsolidated spoil materials from the dredging of the AIWW to the area above the N.C. 24 Bridge/ Causeway is considered to be a major cause of this major shoaling and depth loss problem in the lower estuary. The construction of the bridge and causeway reduced the effective width of the river, blocked off one channel of the river, and presumably acted to contribute to the shoaling problem.

A second major conclusion derived is that many of the seafood resources in the White Oak River are apparently underutilized. Pollution from septic tank effluents and other non-point sources have contributed to this underutilization by placing vast areas of productive shellfish bottoms off limits to commercial fishermen. While the oyster replanting program conducted by the N.C. Division of Marine Fisheries has been successful, a similar program for relaying of polluted clams has not been attempted due to a lack of funds and the restraints imposed by current fisheries regulations. Aggresive intiatives on the part of responsible individuals and agencies will be required to fully exploit the fisheries resource potentials of the White Oak River basin.

7.2 Recommendations (Plan of Action)

Based on the overall findings and conclusions of this report, the following recommendations and/or plans of action are suggested for consideration:

7.2.1 Overall River Basin Management and Control

A. River Basin Math Model. Local interests should request a study to be conducted under the UNC-Sea Grant program to develop a mathematical model of the White Oak River Basin.

1. Output. The math model of the river basin will be used as a management and planning tool to predict future changes and to verify the need for implimentation of proposed structural and/or non-structural solutions to identified problems.
2. Potential Sources of Funds. N. C. Sea Grant College Program.
3. Estimated Cost. $30,000 - $50,000 (to be confirmed by N. C. Sea Grant).
4. Background for Recommendation. Sections 3.8.2, 5.1.1.1, 5.3 and Appendix "C".

B. Comprehensive Watershed Plan. Local interests should press for the reactivation of the PL83-566 Watershed Project on the White Oak River administered by the Soil Conservation Service of the U.S. Department of Agriculture. This PL83-566 project should be broadened in scope to include the entire White Oak River Drainage Basin. The purpose would be to define the impacts that agriculture and silviculture are having on the White Oak River including inputs of sediments and pollutants. The N.C. Department of Natural

Resources and Community Development, (Division of Environmental Management) should be a cooperating agency for the study.

1. Output. A comprehensive watershed plan for the White Oak River Basin. This plan will define problems and propose long term solutions to these problems regarding flood control, sedimentation and diffuse sources of pollution.

2. Potential Sources of Funds. (1) USDA - PL83-566, (2) NCDNR&CD, DEM - PL92-500, Section 208.

3. Estimated Cost. $80,000. (To be confirmed by SCS.)

4. Background for Recommendation. Sections 3.8.2 and 5.3.

C. Improved Management Practices. Local interests should press for implementation and/or application of optimum agricultural, silvicultural and septic tank installation practices throughout the White Oak River Basin. These actions can best be implemented through the appropriate Federal, State and local agencies and authorities (USDA, SCS); U.S. Department of Interior (Forestry Service); N. C. Department of Natural Resources and Community Development (Division of Forestry Resources, Division of Environmental Management); and N. C. Department of Health and County sanitation offices).

(1) Output. Improved and intensified enforcement of existing rules and regulations governing agricultural, silvicultural and septic tank installation practices.

(2) Potential Source of Funds. (No new funding required.)

(3) Estimated Cost. (No additional cost.)

(4) Background for Recommendation. Sections 3.8.2 and 5.3.2.2B.

7.2.2 Fisheries Resources

A. Shellfish Bottom Survey. The N.C. Division of Marine Fisheries should conduct a shellfish bottom survey of the White Oak River estuarine system.

(1) Output. A map showing the location and extent of clam and oyster beds in the White Oak River.

(2) Potential Sources of Funds. (1) Funds appropriated by Carteret, Jones and Onslow Counties and funneled through the N.C. Division of Marine Fisheries; (2) EDA or National Marine Fisheries.[1]

(3) Estimated Cost. $40,000 first year, $40,000 at five-year intervals thereafter to update data to reflect existing conditions;

(4) Background for Recommendation. See Sections 3.9, 3.10 and 5.2.

B. New Clam Management Regulation. The N.C. Division of Marine Fisheries and Shellfish Sanitation Office (through the Marine Fisheries Commission) should adopt new regulations either: (1) allowing closure of specific areas to claming; or, (2) a 3-month statewide closed clam season.

(1) Output. A new clam management regulation will pave the way for the relaying of clams from polluted areas to clean areas for self-cleansing and ultimate marketing by commercial fishermen.

(2) Potential Source of Funds. Special legislative appropriations.

(3) Estimated Costs

(a) Change regulations and conduct public hearings - $5,000.

(b) Enforcement of New Regulation - $5,000 per year to police closed areas.

(c) Shellfish Testing - $5,000 per year to test shellfish for purity and suitability for marketing.

1./ The status of funds from these Federal agencies is uncertain at this time.

(4) Background For Recommendation. See Sections 3.9, 3.10 and 5.2.2.

C. Expansion of Shellfish Relaying Program. The N.C. Division of Marine Fisheries should maintain, expand and enhance its shellfish relaying program in the White Oak River. The program should be expanded to include the stunted oysters in the lower river and enhanced by encouraging the participation of private interests through relay contracts.

(1) Output. The application of this program will increase the utilization of high value shellfish resources in the White Oak River. It will stimulate the local shellfishing industry, and by the ripple effect, it will stimulate the local economy.

(2) Potential Sources of Funds. (1) Special legislative appropriations, (2) Carteret, Jones and Onslow County funds, (3) EDA funds (creation of jobs)1./, or (4) CETA funds.1./

(3) Estimated Costs

(a) Oyster Relay Program - $20,000/year

(b) Clam Relay Program - $15,000/year

(c) Private Relay Program - $20,000/year (for payment of stipened to private individuals to relay shellfish)

(4) Background for Recommendation. See Sections 3.9, 3.10, and 5.2.

D. Research on Stunted Oysters

The Duke University Marine Laboratory should continue its study of stunted oysters in the White Oak River.

1./ The status of available funds from these agencies is uncertain at this time.

(1) Output. A study report which will specify the ideal time locations, conditions and procedures for relaying of stunted oysters within the White Oak River estuary.

(2) Potential Sources of Funds. National Marine Fisheries Service or Sea Grant 1./.

(3) Estimated Cost. $15,000 (To be confirmed by Duke University Research Team.)

(4) Background for Recommendation. Sections 4.2.2 and 5.2.1.1.A.

7.2.3 Sedimentation

A. Expansion of Bogue Inlet Study

Local interests should request the Wilmington District of the U.S. Army Corps of Engineers to expand its Bogue Inlet Study to include investigation of the shoaling and the effect of canalized flows in the lower White Oak River estuary. This study effort should be directed towards a determination of the origin of the sediments and causative factors involving the shoals north of the Route 24 Bridge/Causeway complex. The investigation should include an analysis of the feasibility of removal of these primary shoal areas by shallow dredging and proposed actions to minimize reshoaling processes. The study should also investigate the feasibility of establishing a new hydraulic connection between the restricted estuary and the AIWW. Due to the influence of the Route 24 Bridge/Causeway complex on the hydrology of the area, the N.C. DOT should be involved as a cooperative agency for the study. The rationale for involvement of these combined agencies relates to the nearly simultaneous construction of the AIWW and Bridge/Causeway in the early 1930's.

1./ The status of available funds from these agencies is uncertain at this time.

(1) Output. This study should clearly define the origins of shoaling problems in the lower estuary and determine the economic feasibility of a shallow dredging program or other corrective actions to reduce shoaling rates and to improve the hydraulics of the lower river. Also, the benefits and effects of installing another connection between the river and the AIWW should be defined.

(2) Potential Source of Funds

(a) Corps of Engineers (congressional appropriations)

(b) NCDOT (Planning funds)

(3) Estimated Costs (To be confirmed by the responsible agencies).

(a) U.S. Army Corps of Engineers - $75,000

(b) N.C. DOT - $10,000

(4) Background for Recommendation - See Sections 4.1.3 and 5.1.

Almost all of the above recommendations involve actions by outside agents or agencies; however, it is pointed out that these actions will be taken based only on the initiatives promulgated by local interests who want to solve the problems and restore the White Oak River Basin to its full productive and esthetic potential. Therefore, it is finally recommended that the White Oak River Advisory Council and supporting units of government work cooperatively to pursue the objectives and recommendations set forth in this report.

Respectfully submitted,

HENRY VON OESEN AND ASSOCIATES, INC.

Paul S. Denison, P.E.
Vice President

William E. Burnett
Environmental Planner

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APPENDICES

HENRY VON OESEN AND ASSOCIATES
CONSULTING ENGINEERS
AND PLANNERS

APPENDIX A

ADVISORY COUNCIL REPRESENTATION
AND
MEMORANDUM OF AGREEMENT
WHITE OAK RIVER ADVISORY COUNCIL

APPENDIX A

The White Oak River
Advisory Council

	Name	Affiliation/Representation
(1)	Mr. Kenneth Windley, Jr.	Planning Director Onslow County
(2)	Mr. Charles Daley	Carteret County
(3)	Mr. Andy Ennett	Commissioner Town of Swansboro
(4)	Dr. Alfred Norton	Izaak Walton League and Town of Cape Carteret
(5)	Mr. James Phillips	Commercial Fishing Industry

MEMORANDUM OF AGREEMENT

The parties share a common sense that the White Oak River is a valuable resource which is threatened by continuing siltation at its mouth. We note that fisheries productivity, shellfish productivity, and the normal economic development of the ports of Swansboro and Cape Carteret are constrained by the continuing siltation of the river.

It is the sense of the parties that all possible efforts to reverse the river's decline be undertaken. The following recommendations specify a course of action which will begin the process of the restoration of the White Oak:

(1) The parties hereby form the White Oak River Advisory Council and hereby request the Town Boards of Swansboro and Cape Carteret and the Boards of Commissioners of Onslow and Carteret Counties to each appoint a representative to the Advisory Council. The Issac Walton League and the Fisheries Industry are also requested to appoint a representative to the Council.

The local staff function for the Advisory Council will be performed by the Onslow County Planning Department.

(2) The parties hereby request the appropriate Boards and Councils to endorse the formation of the White Oak River Advisory Council.

(3) The parties hereby request that the Office of Coastal Management receive a joint proposal for the first phase of a technical study of the flushing of the White Oak River. This proposal will be transmitted by the Onslow County Planning Department and endorsed by the Advisory Council.

(4) The parties request each of the four local governments to equally participate in the local matching share for Phase 1 of the technical study.

(5) The parties request participating local governments to endorse the Council's efforts to obtain the widest possible funding base for the completion of the technical study, subject to review and approval by the local Boards and Councils.

Swansboro

Cape Carteret

Onslow County

Carteret County

Issac Walton League

Representing the Fishing Industry

June 9, 1980

APPENDIX B

WORK TASK OUTLINE

WORK TASK OUTLINE

WHITE OAK RIVER SYSTEM STUDY
For The
WHITE OAK RIVER ADVISORY COUNCIL

I. DATA COLLECTION PHASE

Work Task Description: This phase of the study will consist of the collection of existing data on the hydrology, tidal hydralics, sources of pollution, fisheries resources, etc., of the White Oak River. Existing published and unpublished data sources will be carefully and thoroughly scrutinized. Contacts will be made and interviews will be conducted with representatives of all local, regional, state and federal agencies which have conducted (or are in the process of conducting) research on the White Oak River System. Special efforts will be made to contact representatives of the following agencies and institutions: NCDNR & CD, Division of Marine Fisheries and Division of Environmental Management; U.S. Army Corps of Engineers; U.S. Geological Survey; U.S. Environmental Protection Agency: Duke Marine Laboratory, National Marine Fisheries Service, etc. Also, local fishermen and other knowledgeable individuals in the private sector will be contacted and interviewed.

OutPut: The output from the collection of existing data will be a written review of existing conditions of the White Oak River.

II. DEFINE THE PROBLEM(S) PHASE

Work Task Description: This phase of the study will draw upon the results of phase I in order to define the problems in the White Oak River Basin. The existance of such problems as hydraulic system restrictions, sedimentation, disappearance of fish, stunted oysters and point and diffused sources of pollution will be defined.

OutPut: The results of this phase will be a written description of existing environmental problems. Where existing data is insufficient to accurately quantify supposed problems, recommendations for additional study will be made.

III. PROPOSE SOLUTIONS

Work Task Description: This phase of the study will involve the formulation of structural and/or non-structural solutions to the problems defined in Phase II.

OutPut: Output from this work task will be proposed solution(s) to identified problems, including conclusions and recommendations for future work.

IV. COORDINATION AND REVIEW

Work Task Description: The preliminary results of the study efforts defined above will be reviewed with the White Oak River Advisory Council in order to receive their input.

OutPut: The results of this effort will be a critique of the study effort and an opportunity for additional input and guidance.

V. FINAL REPORT

Work Task Description: All of the data gathered in the above phases will be synthesized into a final written report to the Advisory Council. The report will be prepared in bound, brochure form and will include appropriate illustrations and text to facilitate public understanding and acceptance. A suggested report outline is attached.

OutPut: 10 copies of the final report will be provided to the Advisory Council.

APPENDIX C

DESCRIPTION OF MATHEMATICAL MODELING STUDY
FOR THE WHITE OAK RIVER

Developed By:

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STUDY OF THE WHITE OAK RIVER BASIN

1. The proposed Numerical Analysis:

It is proposed to study the White Oak River Basin in regard to the pollutant dispersion and sedimentation. The present attempt is to analyze the area under consideration (Fig. 1) using a mathematical model with a view to adopt appropriate measures that will eliminate the problems of siltation and pollution. The mathematical model will be used to numerically analyze the hydrodynamics and the associated pollution and sediment transport. An outline of the data to be collected to efficient implementation of the model is given at the end.

In the regions where the flow can be considered to be one dimensional (i.e. along the axis of the river, such as near Webb Creek) a 1-D depth averaged Finite Element Model will be used. This will then be coupled to the 2-D model required in regions where the river width is large enough to entail predominant flows at right angles to the axis also. The discretization into finite elements in conformity to the above is shown in Fig. 2.

The analysis will be carried out in two steps:

(i) Resolution of Hydrodynamic Parameters, (Fig. 3). The water-level η and the velocity components will be the variables in this exercise.

(ii) Resolution of Salinity, Pollutant and Sediment Concentration.

1.1 Outline of The Mathematical Models:

1.1.1 Governing Equations

Resolution of Hydrodynamics; the hydrodynamic equations of momentum and continuity will be used.

(a) One-dimensional model:

$$\frac{\partial v}{\partial t} + v\frac{\partial v}{\partial s} + g\frac{\partial \eta}{\partial s} + g\, S_f = 0$$

$$\frac{\partial \eta}{\partial t} + \frac{\partial}{\partial s}\left\{ v(h+\eta) \right\} = 0$$

where v = depth averaged velocity
s = distance along river
η = water level above a horizontal datum

g : acceleration due to gravity

S_f : friction slope along s

h : depth to bottom of the river from the horizontal datum

t : time.

(b) TWO-dimensional Model:

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + g\frac{\partial \eta}{\partial x} + g S_{f_x} = 0$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + g\frac{\partial \eta}{\partial y} + g S_{f_y} = 0$$

$$\frac{\partial \eta}{\partial t} + \frac{\partial}{\partial x}\left\{u(h+\eta)\right\} + \frac{\partial}{\partial y}\left\{v(h+\eta)\right\} = 0$$

Here, x and y are the axes in the horizontal plane and u and v are the corresponding velocity components.

Resolution of Concentrations; the Diffusion-Advection Equation will be used.

(a) One-dimensional Model:

$$\frac{\partial (Ac)}{\partial t} + Q\frac{\partial c}{\partial s} + KAc = \frac{\partial}{\partial s}\left(D_s A \frac{\partial c}{\partial s}\right)$$

where A = area of cross-section of flow

C : concentration

Q : volume rate of flow

D_s : Diffusion coefficient

k : rate constant of decay

(b) TWO-dimensional Model:

$$\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} = \frac{\partial}{\partial x}\left\{D_x \frac{\partial c}{\partial x}\right\} + \frac{\partial}{\partial y}\left\{D_y \frac{\partial c}{\partial y}\right\} + k$$

D_x and D_y are the diffusion coefficients along x and y respectively.

In the case of sediment transport and pollutants capable of settling, the equations given above will be modified by including the following term on the right hand side in each of the two equations given above:

$$\frac{\partial}{\partial z}(w_z c)$$

where z is the vertical direction and w_z is the settling velocity in that direction.

1.1.2 Boundary Conditions

Measured values of hydrodynamic parameters (either η or velocity) at the end control sections in the 1-D Model and at the boundaries in the 2-D Model will serve as the boundary conditions. Once the model is validated by comparing the measured and computed values at the intermediate points, boundary conditions for future flows can be synthesized as delineated in Ref. 3 (a copy of this reference is enclosed.).

1.2 The Numerical Model:

The region under study is discretized into one-dimensional line-elements or 2-D triangular elements as the case may be (Fig. 2). The elements are interconnected at the nodes. Discrete values are ascribed to the parameters at these nodes. They are called the nodal variables. These nodal variables are variant in time only as their spatial determination is served by the geometric position of node.

The governing equations described above will be reduced to a system of algebraic equations using the Galerkin procedure. Such an approach can produce a complete space-time history of ~~for~~ the field parameters (such as concentration) at the nodes of the elements, i.e. the nodals variables are evaluated. Obtaining the values of the parameters at any other point is easily done using interpolation inside an element and the associated nodal values. A description of the Galerkin Finite Element technique is given in Ref. 4.

2. Data Collection:

The numerical analysis of the area under consideration requires data on the following ~~four~~ six items:

(i) cross-section of the river
(ii) water level fluctuations
(iii) velocity of flow
(iv) Density variations
(v) Salinity
(vi) Sediment and Pollutant Concentration

(i) The river cross-sections are to be obtained at as many sections as possible and especially where the banks turn sharply. Some of the desirable places are shown by green lines on the map (Fig. 1).

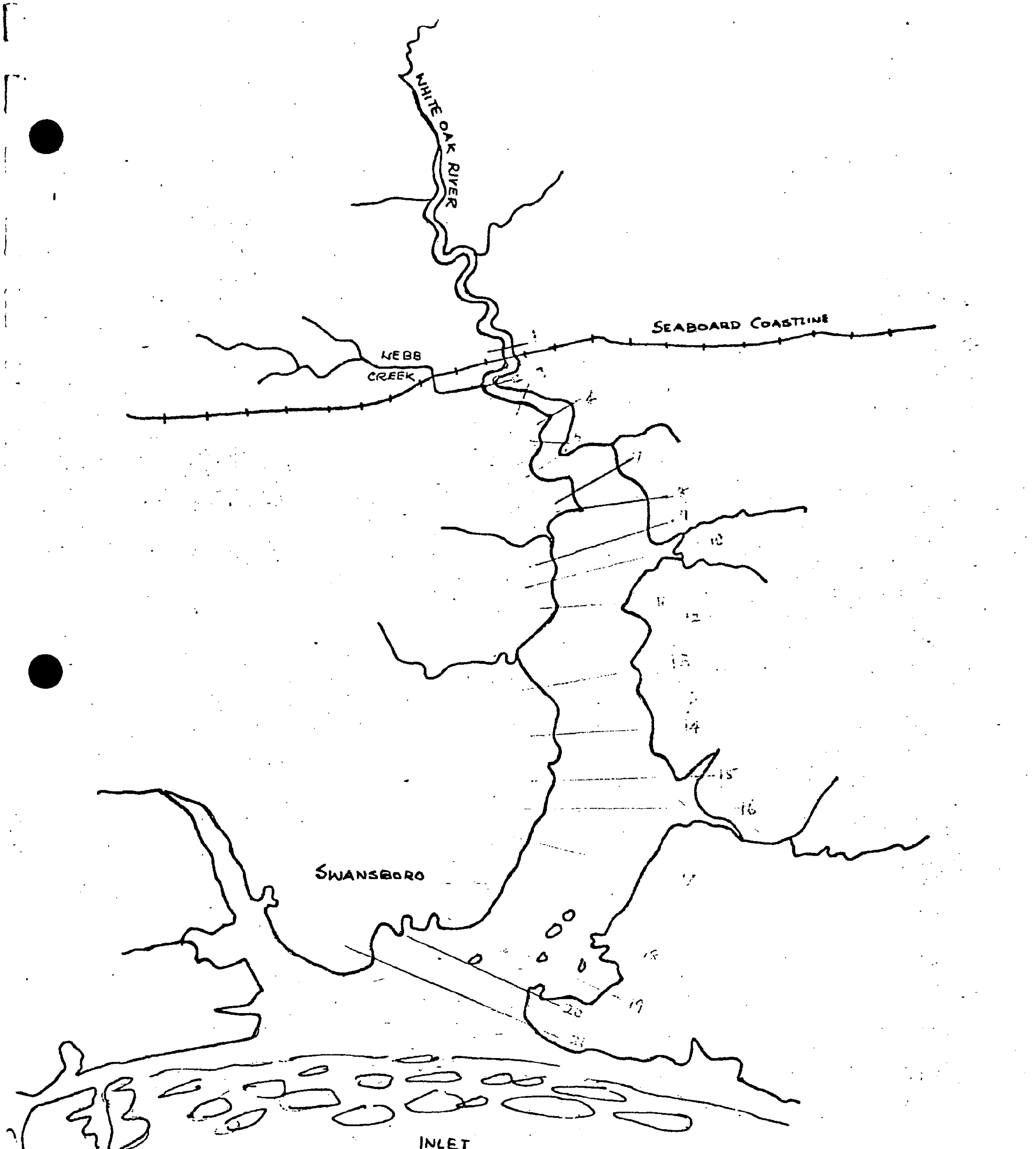
(ii) The time-history of water-levels are also needed at these locations. If the width of the river is 10 m or less one reading in the middle would be sufficient; otherwise, the numbers of readings along the width should be increased; say, one reading every 10 m or 25 m depending on the width. In such cases the water-levels near the banks should also be measured; these will serve as boundary conditions for a 2-D model.

(iii) Velocity readings are to be taken at the same locations where water-levels are recorded. On the wide sections of flow (i.e. width > 10 m) velocity readings will have to recorded along with the directions in order to compute the velocity components. If the depth is more than 4 m, velocities will have to be recorded at the surface and at mid-depth.

(iv) Density recordings: These are to be made at various depths (say, at intervals of 1 m). These will help in identifying the saline wedge and the associated probable location of sedimentation.

(v) Salinity recordings will be used to predict the diffusion of saline water from the sea. The associated saline concentration will be incorporated in the numerical model. The locations for these recordings are the same as for density.

(vi) Sediment & Pollutant Concentration - the explanation is the same as for salinity above.

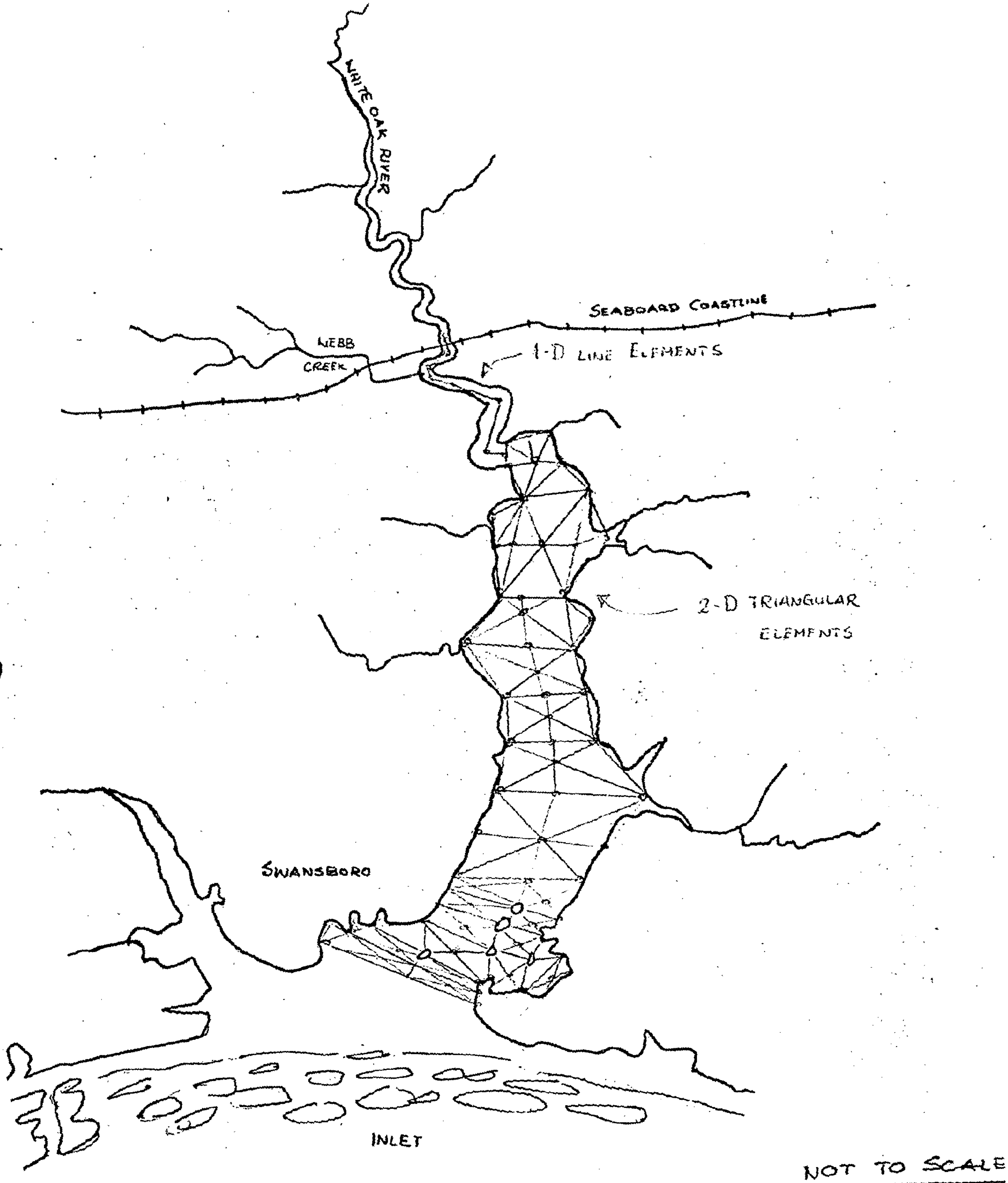


NOT TO SCALE

WHITE OAK RIVER BASIN

STUDY AREA

Figure 1



WHITE OAK RIVER BASIN

STUDY AREA

Figure 2.

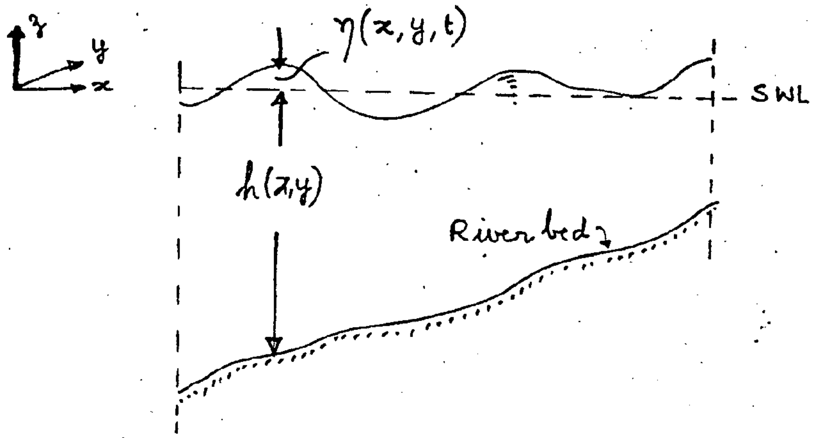


Figure 3. Definition Sketch

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Flow in Tidal Inlets

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1 INTRODUCTION

One-dimensional gradually varied flow analysis of tidal hydrodynamics in inlets has been the subject of study in the last few decades and many mathematical models have been developed based on those studies. A common feature in all these models is that the boundary conditions at the ends of the reach are supplied from measured values of stage, discharge or velocity. These boundary conditions form an integral part of the mathematical models. In the case of implicit schemes, without the supply of these boundary conditions there will be more unknowns than equations. Even though in the explicit schemes they are not needed to supply enough equations it is obvious that the flow will not be properly simulated without imposing proper end conditions of flow.

Normally two end conditions will be required, the upstream and downstream conditions, even though in a net work of channels there will be more than two end conditions. Of these two, the upstream condition is usually the forcing function and the downstream one is the result of the flow due to the forcing function. The downstream condition depends on what happens to the flow outside the system. In other words, it depends on the shallow water wave reflections from the continuation of the channel beyond the downstream end of the system considered. These reflections are characterized by the expansion or contraction of the channel, the rate of change of the side slopes and other channel characteristics. As mentioned earlier, the downstream end condition is supplied from measured values of flow parameters so that the channel features (outside the system) mentioned above are automatically simulated. However, if it is required to know the response for any given forcing function the corresponding measured downstream values may not be available. This means that the downstream boundary condition cannot be imposed in the usual way. This study describes a method by which the downstream boundary condition can be imposed in the absence of measured downstream response to a given forcing function. However, the method presupposes that measured values for at least one forcing function are known as part of the features of the channel or channel systems.

2 PARAMETERS INVOLVED

The rate of change of velocity or stage at a point is a function or geometric and dynamic parameters. The geometric parameters include the shape of the channel cross-section and the rate of change of that section beyond the point under consideration. The stage η (see Figure 1) and velocity U at the point are the dynamic parameters, in addition, of course, to the acceleration due to gravity. However, when looking for the rate of change of velocity or stage at an end-section it should be recognized that such rates can be different for the same stage and velocity depending on whether the flow is accelerating or decelerating and whether the flow is inward or outward of the inlet.

By grouping the geometric and dynamic parameters to form appropriate non-dimensional numbers it would be possible to predict with a fair amount of accuracy the time rate of change of velocity or stage at the end sections of a channel system. In the present study, the rate of change of velocity $\partial U/\partial t$ has been used as the downstream boundary condition.

3 APPLICATION OF THE π-THEOREM

A functional relationship of the dynamic parameters involved can be written as follow, remembering that we are looking for $\partial U/\partial t$.

$$F(\dot{U},\ U,\ g, \eta) = 0$$

where U is the velocity, $\dot{U}$ is time-derivative of U, g the acceleration due to gravity and the water level.

Using η and g as the repeating variables, the non-dimensional numbers π_1 and π_2 are

$$\pi_1 = \eta^a g^b \dot{U}$$

$$\pi_2 = \eta^{a_1} g^{b_1} U$$

On applying the dimensional equations, it is found that a = 0, b = -1, $a_1 = -\frac{1}{2}$ and $b_1 = -\frac{1}{2}$. Therefore,

$$\pi_1 = \dot{U}/g$$

$$\pi_2 = U/\sqrt{g\eta}$$

As can be expected, π_2, the Froude number of flow is a governing factor.

4 DETERMINATION OF $\partial U/\partial t$

From a given set of velocity-stage relationships at a given end of a channel system a relationship between the two non-dimensional numbers π_1, and π_2 is obtained using a least squares fit of fourth order polynomial. From this relationship one can compute $\partial U/\partial t$ once the velocity and stage at the point for a given time is known. This $\frac{\partial U}{\partial t}$ is imposed as the downstream boundary condition. The steps involved in the procedure are shown in the accompanying flow charts (see Figures 2 and 3).

The procedure as outlined was tested using field data of the Carolina Beach Inlet, N.C., U.S.A. This inlet (see Figure 4) comprises of a small inlet-channel connecting the ocean to the Atlantic Intracoastal Waterway. That part of the channel system taken for study is shown in the dashed section of Figure 4. The Galerkin finite element approach coupled with a Hermitian Cubic shape function was used to analyze the inlet. The channel system requires the rate of change of velocity, i.e. $\partial U/\partial t$ at the two points range 1 and 2 Independent relationships between π_1 and π_2 were obtained for these two points in order to impose the two downstream boundary conditions. The upstream boundary condition was the forcing function which is the tidal fluctuation at the mouth of the inlet.

The results of the analysis are shown in the form of tidal fluctuations at range 1 and range 2 (An example is given in Figure 5).

6 CONCLUSION

A method for supplying downstream boundary condition in the absence of measured data for any given forcing function has been developed. This method is based on non-dimensional members which govern the dynamics of flow. These numbers were determined by a simple application of the π-Theorem to the dynamic parameters of flow.

The above method was applied to the Carolina Beach Inlet analysis. As shown by Figure 5 the method yields values which are in good agreement to the measured tide at the two points considered. This, no doubt, depends on the numerical method of analysis also. The non-dimensional numbers can be used to yield the downstream boundary conditions for any numerical method chosen to analyze the flow provided $\partial U/\partial t$ is the downstream condition needed for all time. If it is $\partial\eta/\partial t$, then a different set of non-dimensional numbers are required.

The advantage of the method developed here is that one can know the response of a channel system to a hypothetical but possible forcing function for which measured downstream values are not available. This situation is especially relevant to power canals, inlet channels where the flow is affected by man-made alterations in river discharge or construction, etc.

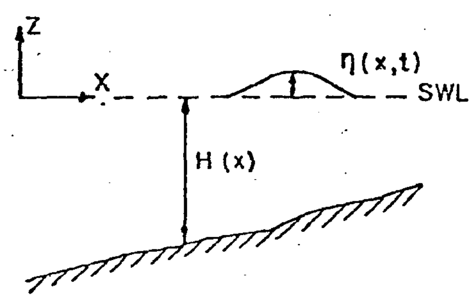
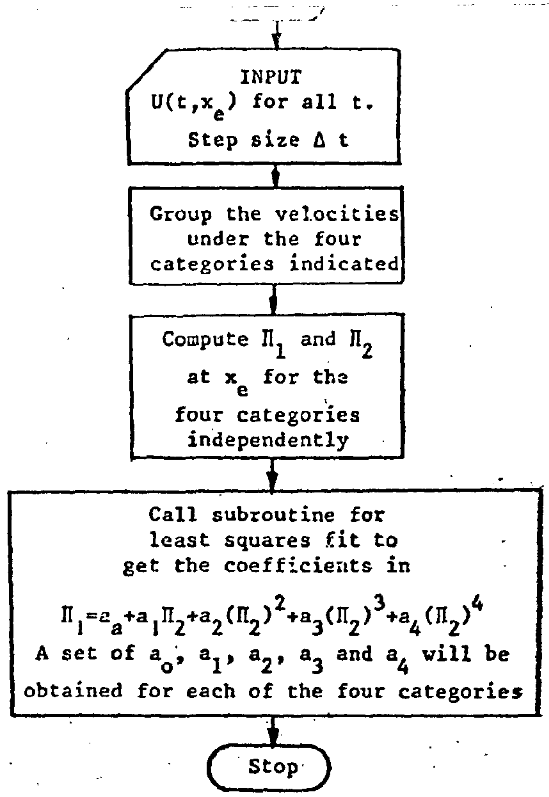


Figure 1. Definition Sketch



U = one-dimensional velocity

x_e = x coordinate of the channel end

Π_1 = $\dot{U}/g$

Π_2 = $U/\sqrt{g\eta}$

Figure 2. Flow Chart

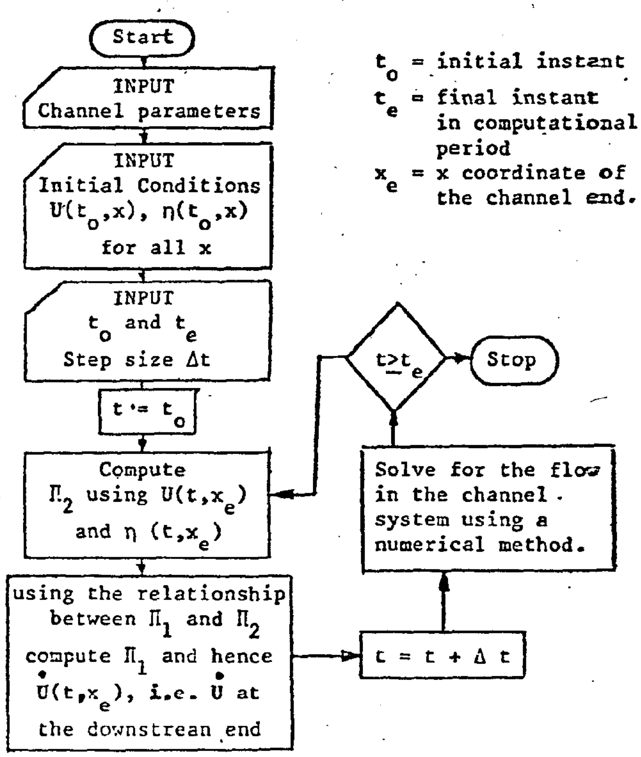


Figure 3. Program Flow Chart

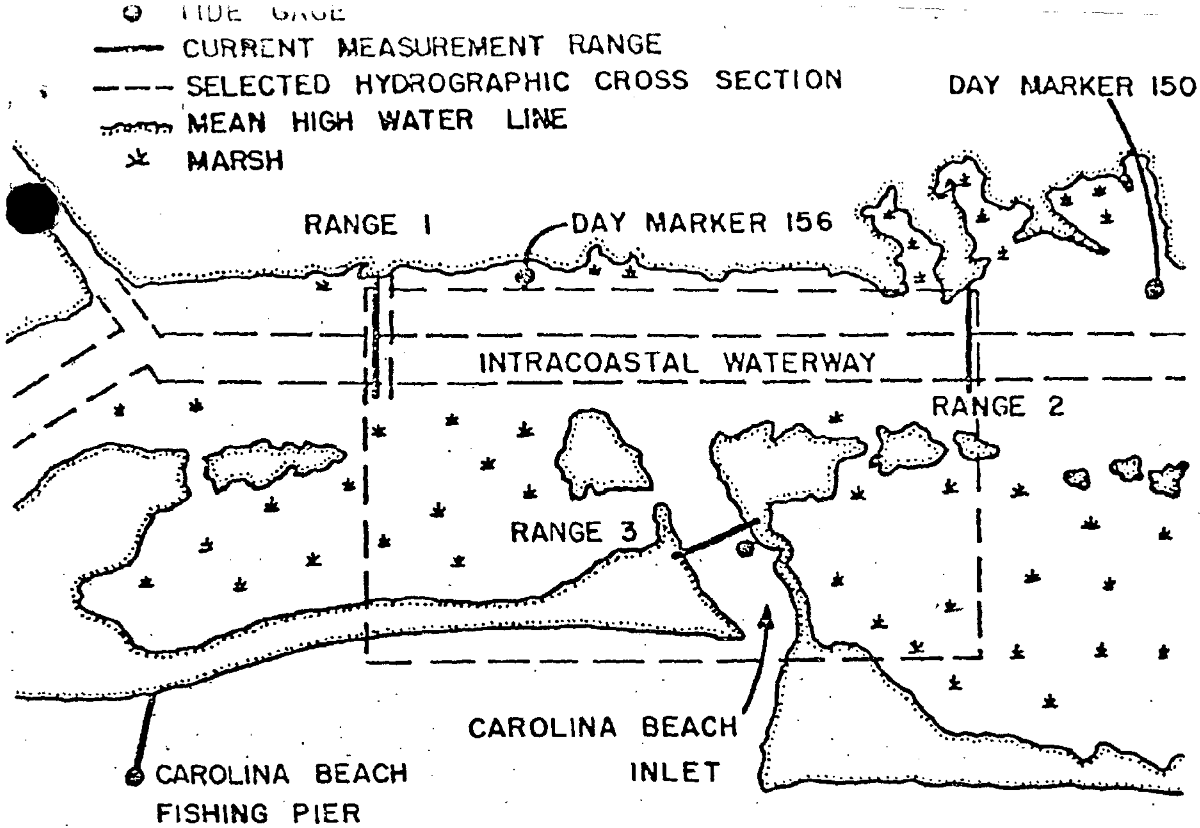


Figure 4. Carolina Beach Inlet.

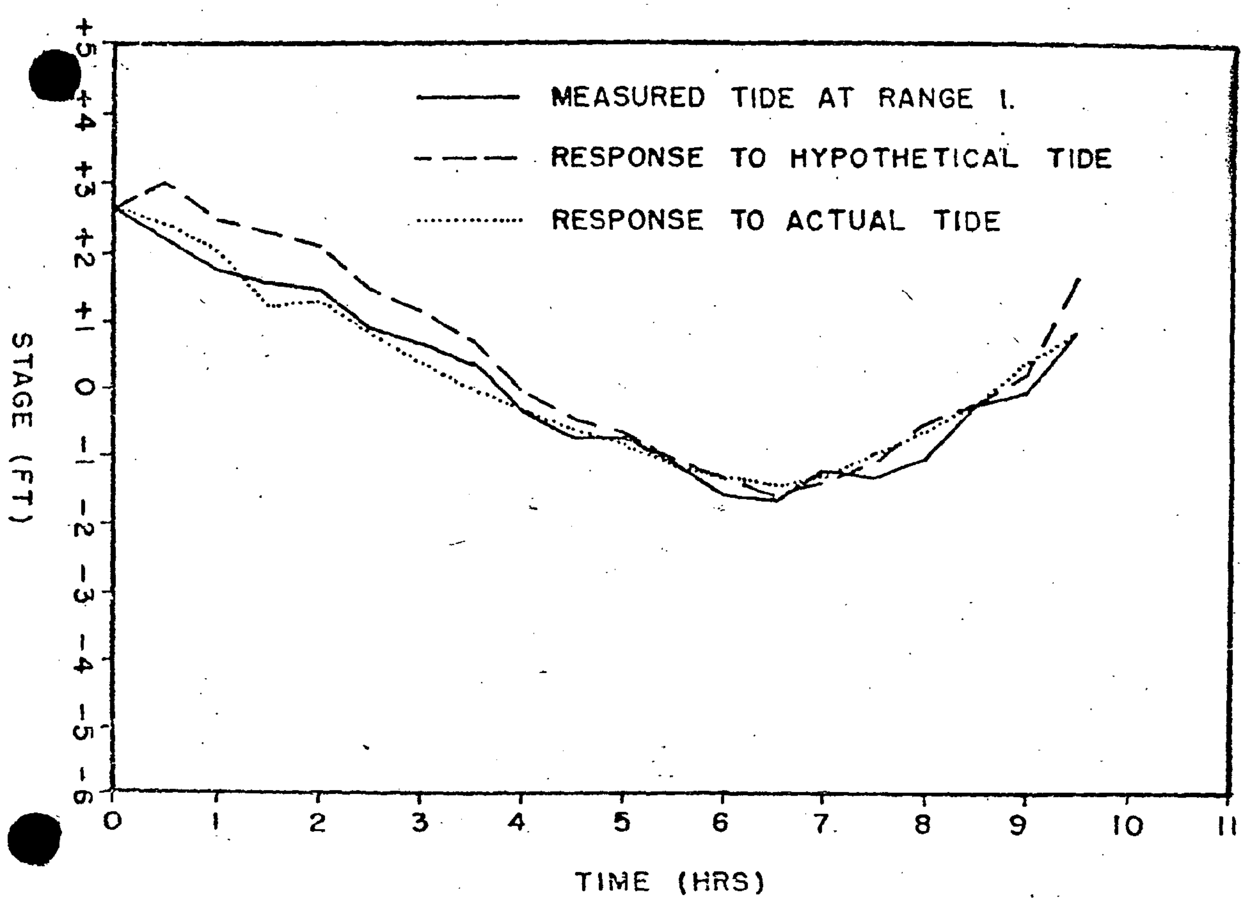


Figure 5. Tidal Fluctuations at Range No. 1.

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